The

ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

VOL. IV. No. 6 JUNE, 1943

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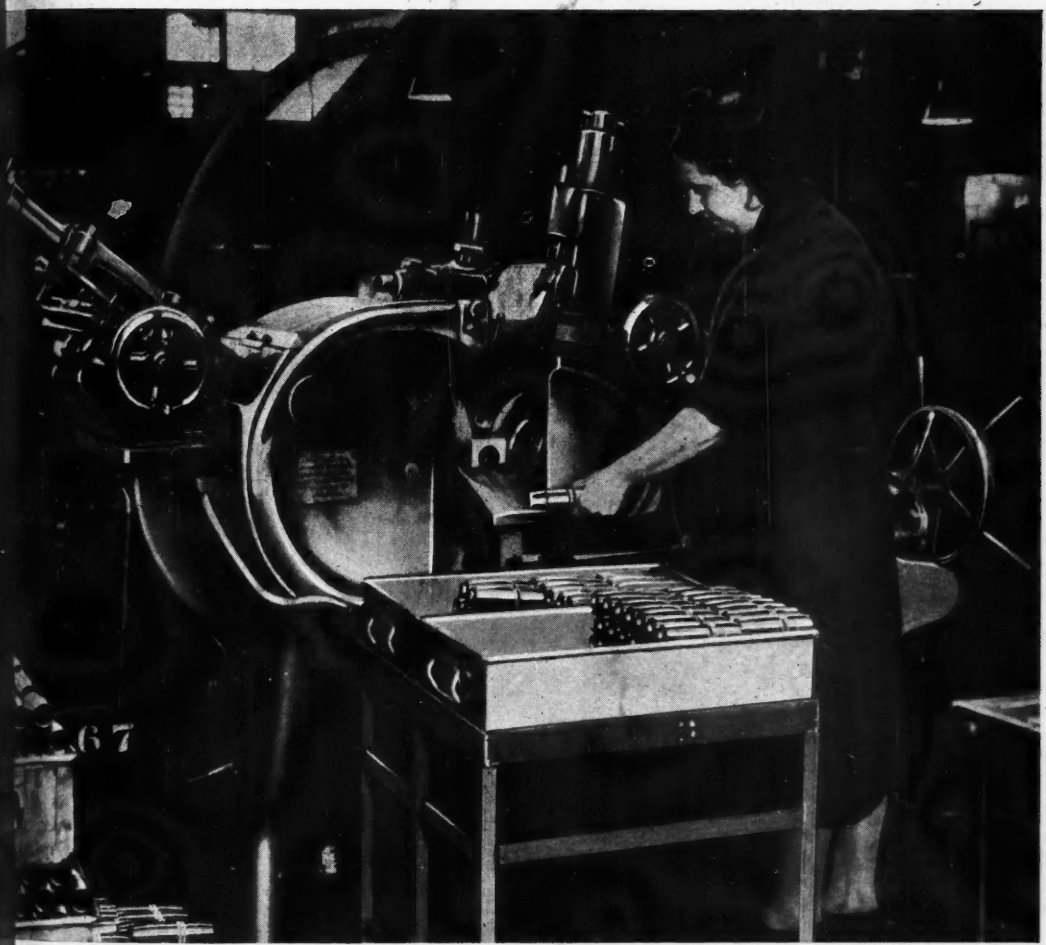

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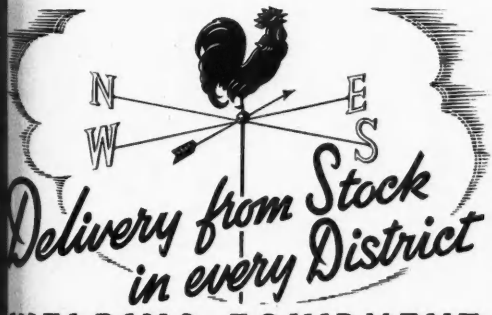

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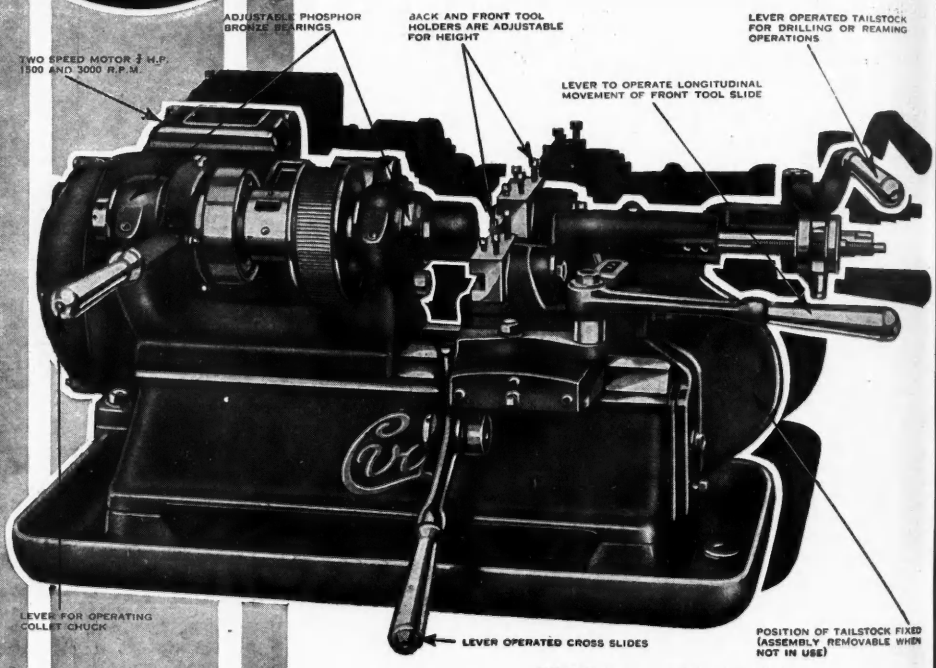
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PROGRESS IN ENGINEERING KNOWLEDGE DURING 1942

By P. L. ALGER and JAMES STOKLEY. (From *General Electric Review*, Vol. 46, No. 2, February, 1943, pp. 90-137).

Materials Engineering.

INVESTIGATORS are delving deeper and deeper into the ultimate nature of matter to correlate atomic structures with physical properties. Thus the 20 million volt induction accelerator is now a reality and a 100-million volt machine approaching completion. This marvelous new device will produce an electron beam many times more powerful than ever made before, opening the way to a completely new field of atomic and X-ray research.

Alternate Materials.

Rubber, silk, shellac and dozens of other materials used since time immemorial are rapidly being replaced by substitutes or synthetics and may never regain their former importance. It has become necessary for the engineer to recast his whole philosophy and adjust his methods of thinking to re-design on the basis of the curtailed list of available materials. Not only has the use of critical material been reduced, but in many instances ways have been found to reduce the time and cost of production, while maintaining, or even improving quality.

Surface Chemistry.

A method has been found to photograph the changes that occur in the snowflakes. This—one of plastic replicas—consists in covering the flake with a cold diluted solution of a resin such as polyvinyl formal in ethylene dichloride (*Fig.* 1).

A similar method has proved the value in studying metallographic specimens with the electron microscope. With this instrument in its customary form, specimens for examination must be transparent to the electron beam, a consideration which prevents the direct inspection of the usual polished and etched metal samples. Thus it is necessary to prepare a replica of the surface and to examine this instead.

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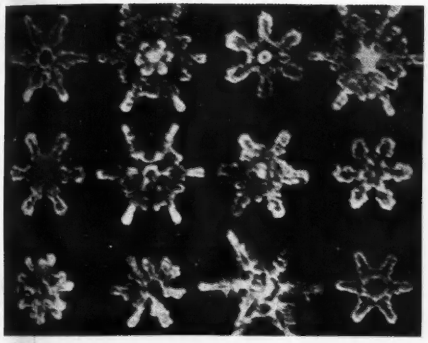

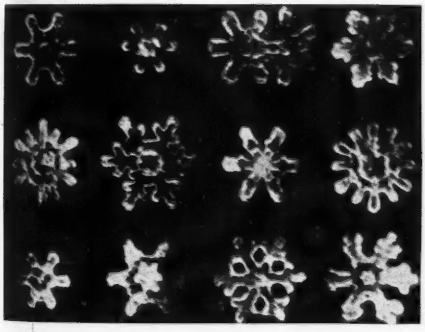

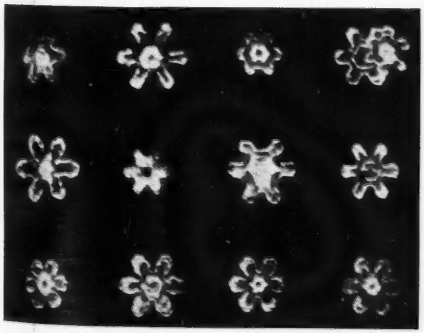

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Fig. 1. Photomicrographs of typical snowflake replicas made during a snowstorm. All of them were made at the same magnification.

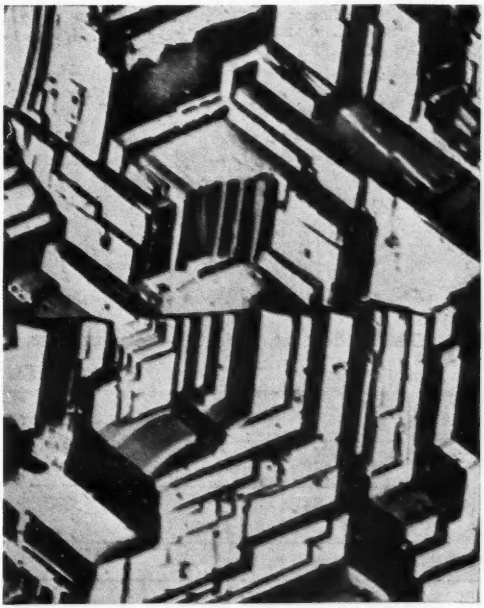

Fig. 2. Photomicrograph of a replica obtained from an etched quartz crystal, showing the contact between a primary and a penetration crystal.

Highly satisfactory results have been obtained by applying a polyvinyl formal solution in ethylene dichloride or dioxane to the metallographic sample and stripping it either dry or under water.

The upper surface of such a film is smooth, while the lower surface reproduces faithfully the minute irregularities of the metal. *Fig.* 2 illustrates a photomicrograph (200 × magnification) of a replica obtained from an etched quartz crystal, showing the contact between a primary and a penetration crystal.

Plastics.

The plastics industry was growing rapidly in many directions but the war brought a still greater acceleration; its facilities being turned to the manufacture of millions and millions of essential parts.

Laminated material has lately assumed new importance. High pressure laminating requires pressures of the order of 1000-2000 lbs. p.s.i. at temperatures of 150-165° C. for phenolics and 130-150° C. for ureas. Pressures of 100 lbs. p.s.i., or (usually) very much lower and at considerably lower curing temperatures, are used in low-pressure laminating. The method is particularly adapted to non-structural or semi-structural parts not having to carry heavy loads. *Fig.* 3 and the like are good examples.

Dielectrics.

Great advantages are gained by use of polyvinylacetal type resin for magnet-wire insulation: Formex-wire. *Fig.* 4 shows the marked superiority, determined by an abrasion testing machine, in comparison with earlier insulating materials.

Cellulose insulation and resin bonded composition cork is widely used.

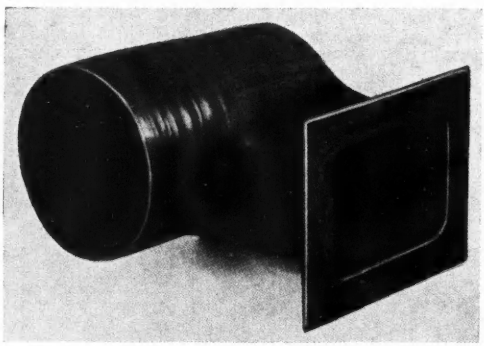

Fig. 3. This air duct was laminated without pressure.

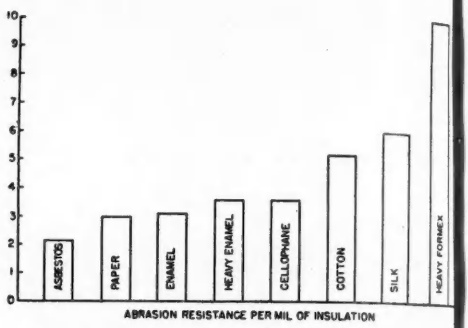

Fig. 4. Comparison of the abrasion resistance of heavy Fornex film to other insulating materials.

Metallurgy.

The field of powder metallurgy includes the manufacture of different parts with outstanding physical characteristics. Iron, cobalt and nickel powders are pressed and sintered in furnaces of controlled atmospheres, the temperature and time being the most important factor for maximum density.

Silver - brazing alloys are shown on Table I.

Tantalum in the form of carbide proved useful in steel-cutting tools, while the metal also has been used in some of the newer radio equipment. An interesting application of metallic tantalum is shown in *Fig.* 5 as plates, screws or pins in bone fixations.

Zirconium in heat exchangers for the evaporation of hydrochloric acid has been proved of excellent corrosion resistance.

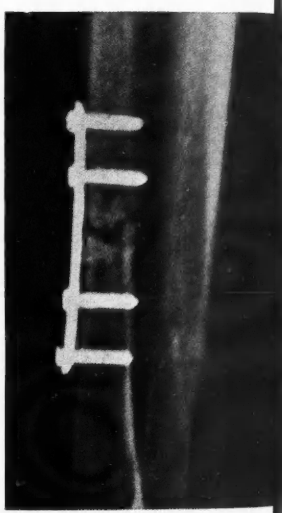

Fig. 5.

TABLE I.

General Electric Company Designation	COMPOSITION, PER CENT					Lowest Melting Point C	Brazing Temperature A	Remarks
	Silver	Copper	Zinc	Cadmium	Phosphorus			
B20F2	50	34	16	.....	.....	690	775	General-purpose alloy. Wide melting range permits large fillets to be built up.
B20F5	50	16	16	18	.....	627	635	General-purpose alloy. Fine flowing qualities.
B20A4	30	38	32	.....	.....	745	790	Low-cost alloy. Used on heavy work where overheating danger is not great.
B20A6	15	80	.....	.....	5	640	700	Used on practically all copper-copper joints. Self-fluxing on copper. Suitable for brass using flux. Never used on steel; embrittlement results.

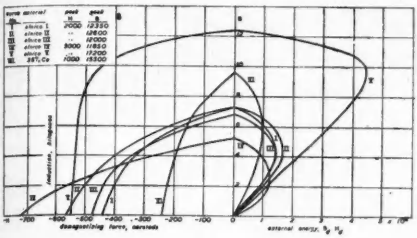

Fig. 6. Demagnetization and energy curves of alnico type of permanent magnets.

Magnetic Materials.

Metallurgical science has produced two principal kinds of magnetic materials :—one where high permeability and low hysteresis are required, the other for permanent magnets. Alnico is the foremost alloy for permanent magnets. As may be seen in *Fig.* 6, recent improvements have increased the external energy factor about threefold over the best previous materials. Great savings are to be expected when full use is made of these improved alloys, with their lower costs per unit of magnetic energy.

High Strength Metals.

A 100,000 hr. high-temperature creep test of four rods of nickel-chrome-molybdenum steel came to an end in 1942. This test is the longest on record. The rods were subjected to a constant temperature of 842° F. and to stresses of 13,000, 17,000, 21,000 and 25,000 lbs. p.s.i. Their final extensions were : 0·928, 1·398, 2·729 and 4·166 mils per inch of length.

When steel is maintained under stress at high temperatures for long periods of time, carbide spheroidization occurs, causing a gradual weakening with consequent increase in the creep rate. It has been found that complete spheroidization occurred of a typical ·5% molybdenum steel in 1500 hrs. at 1292° F. without stress.

By heating cold-worked brass for several hours at about 350° F., the properties are improved as shown in *Fig.* 7. The same effect occurs probably in some degree with all cold-worked and aged solid-solution alloys.

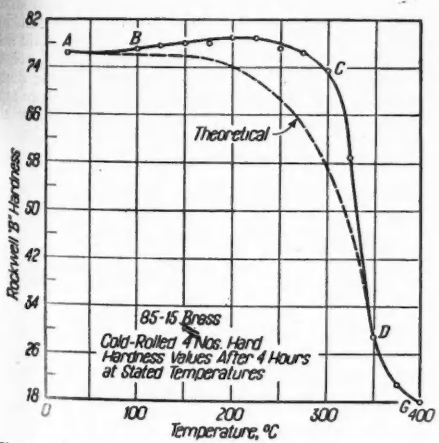

Fig. 7. Hardness values of 85-15 cold-rolled brass after four hours at stated temperatures.

Manufacturing.

Production of drawn tubing has been increased with the use of carbide dies and mandrels. These have been used of sizes from ·013 in. (for hypodermic needles) to 3·5 ins. Some carbide mandrels have run up to 100 miles of tubing, while the average has a drawing life of around 40 miles. One important use has been in the production of cartridge cases.

Carbide tools and automatic precision controls have been applied to large boring mills. The tool will automatically take a cut and stop within ·002 in. Novel thread cutting methods were required for the extremely accurate lead screws, the accumulated error in a 13 ft. screw length being less than ·001 in.

Welding.

A study of electrode DIA in arc-welding has shown that the use of large diameters of rod is desirable. This reduces the time for depositing a given weight of metal.

One important development in welding was the appearance of new heavily-coated electrodes for A.C. suitable for high quality vertical and overhead welding. Hitherto D.C. was necessary for welds of these types to meet A.W.S. specifications. The new A.C. electrode AWS class E—6011 gives 72,000 lbs. p.s i. strength, 27% elongation. This development has released many D.C. units for other work.

In resistance welding, the pulsation process is assuming great importance as it enables two pieces of steel as thick as one inch to be spot welded instead of arc welded.

Heat Transfer.

New and more accurate equations have been established for conditions in the semi-turbulent flow, when the Reynolds number lies between about 3,500 and 11,000. The principal conclusions reached were :—(1) The surface-heat transfer coefficient is directly proportional to fluid velocity. (2) The temperature drop of the fluid due to heat transfer during its passage through the tube is independent of the velocity of flow.

Turbines.

In certain catalytic petroleum refining processes, carbon is deposited on the catalist. The carbon must be burnt off under pressures as high as 300 lbs. p.s.i.

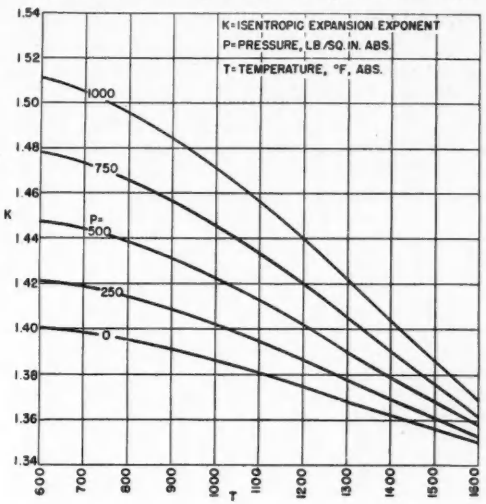

Fig. 8. Isentropic expansion exponent for Nitrogen (N_2).

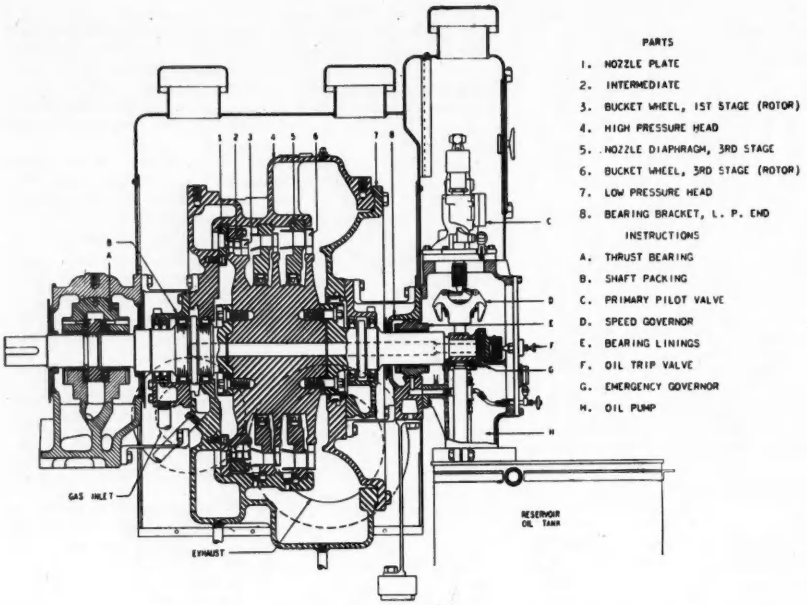

Fig. 9. Cross-sectional view through a 3500 H.P. flue-gas turbine.

This gives rise to a steady flow of flue gas, containing both heat and pressure energy. This has opened a field for exhaust-gas turbines in the chemical industry.

To aid the design of such turbines, a study of the properties of industrial gases was made. One example is shown on *Fig.* 8. *Fig.* 9, shows a cross section of a 3500 H.P. three stage flue-gas turbine, having stainless steel rotor, buckets and nozzles, stellite valve trim and special cast-iron interior packing selected to minimize corrosion.

Transformers.

A major factor by modern high voltage transformers is the scientific design of electrostatic shields, which control the distribution of transient voltage stresses. Many transformers employ the concentric cylindrical coil construction, this has the advantage that the conductors have their shortest dimensions at right angles to the leakage flux assuring minimum eddy-current losses in the copper.

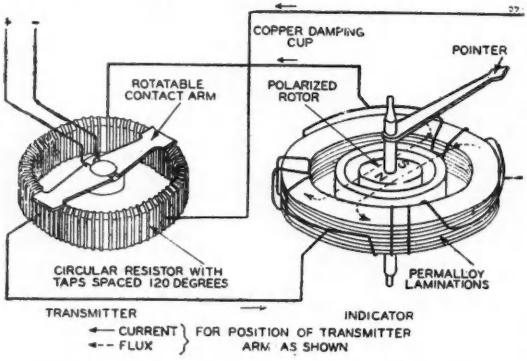

Fig. 10. D.C. Selsyn Remote Position Indicator.

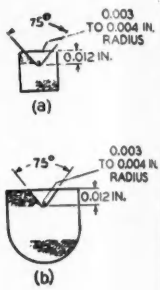

Fig. 12. (a) Cross-section of a sapphire jewel as used for miniature instrument bearings. (b) Cross-section of a glass-jewel.

Voltage Regulators.

A new form of static voltage regulator was devised to prevent the large voltage changes that occur when a variable load of low power factor is supplied from a high impedance a-c system. The regulator consists of a non-linear reactor and capacity combination.

Remarkable progress was made in designing direct acting voltage regulators for d-c aircraft generators.

Electric Instruments.

A search for a system of tele-metering for aircraft use, lighter and simpler than the a-c selsyn equipment used for many years in marine service, had led to the development of the d-c selsyn equipment. This comprises a circular rheostat transmitter, tapped at intervals of 120° and these taps are connected to similarly spaced taps on the receiver. As indicated in *Fig.* 10, d-c is supplied to opposite points on the transmitter coil through rotatable contact arms and the resulting currents in the receiver coil produce a magnetic field that follows the position of the transmitter. A pointer attached to a permanent magnet pivoted in the centre of the receiver gives an indication of the pressure temperature liquid level or other desired quantity on the instrumental panel of the 'plane. An outstanding ad-

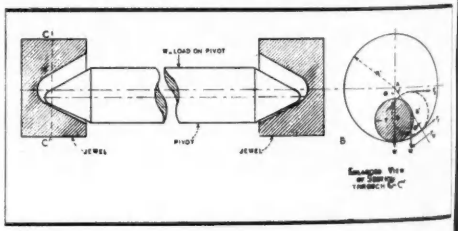

Fig. 11. Instrument bearing assembly for a horizontal pivot shaft mounted in V-shaped jewel bearings. (B) Note that when pivot turns there is an initial roll of the pivot in the bearing after which a sliding action takes place.

vantage of this system is the high ratio of torque to weight obtained.

The accuracy of indicating instruments is largely affected by the friction in the bearing which normally is formed of a cone-shaped pivot with rounded point resting in a V-shaped jewel. *Fig.* 11 illustrates the bearing assembly for a horizontal shaft and shows how the pivot first rolls then slides as it turns. For good design, the pressure should be in order of 400,000-500,000 lbs. p.s.i.

The making of these sapphire "Vees" or jewel bearings is a highly specialised art and nearly all the equipment and personnel are in Switzerland. With the supply cut off, intensive work was done on alternate materials resulting in the development of a special glass Vee, *Fig.* 12.

Measurement.

In a new gonioreflectometer, tests were made of the specular reflectance of over a hundred metal mirrors of 37 different kinds, over angles from 15 to 82.5°. Silver proves best, with aluminium second. *Fig.* 13 shows the reflectances for some of the best metals as first surfaces evaporated on glass.

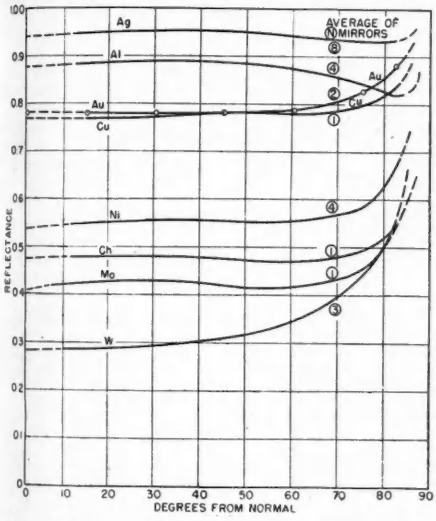

Fig. 13. Measurements on the metal or first surface of eight kinds of metals gave these curves for the angle-reflectance characteristics. The numbers in the circles indicate the number of sample mirrors used to get an average value.

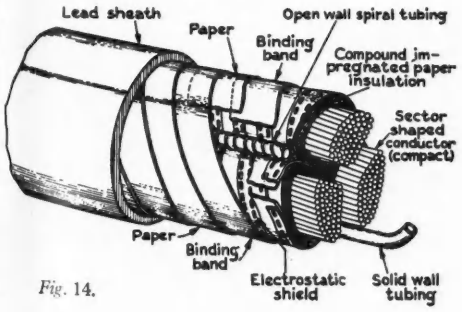

Fig. 14.

Cables.

The first installation of low-pressure gas-filled cable of 15 kV rating in 1938 with a maximum gas pressure of 15 lbs. p.s.i. was followed by medium pressure cables of 40-69 kV rating with 24-40 lbs. p.s.i. pressure and high pressure cables for 69 to 138 kV systems with pressures from 150 to 200 lbs. p.s.i. These cables have impregnated paper insulation with lengthwise channels for the free flow of nitrogen-gas as shewn in *Fig.* 14. The solid wall tubing with occasional gas openings provides assurance that the ducts will not be shut off by compound flow.

Feeder regulator provides an economic means of improving voltage regulation. *Fig.* 15 for example indicates that addition of a regulator at the midpoint of a 2.8 mile feeder supplying a 1,000-Kva distributed load, saved nine tons of copper as compared with increasing the size of the feeder to get the same voltage drop.

Circuit Protection.

Tests were made on a 15 kV 1,500,000 kVA breaker and closed currents as high as 111,000 amp. thus building up a great deal of confidence in the air blast breaker principles. Field tests on a 138 kV air blast circuit breaker of novel design further indicated the soundness of these principles. Successful operation depends to a large extent on a supply of moisture-free compressed air. Study and trial indicated that a compression-expansion system of moisture removal is highly satisfactory for this purpose. The air is first compressed to about 1,000 lbs. p.s.i. pressure, the precipitation is drained off and the air is reduced to working pressure of about 350 lbs. p.s.i.

Industrial Heating.

A great expansion of inductive heating is taking place not only for surface hardening of steel parts, but also for brazing and assembly of all sorts of devices such as glass-to-metal seals. It has been found that each range of frequencies has a distinctive field of use. Power frequencies from 1,000-12,000 cycles supplied by 20-1,200 kW. inductor generators are used for surface hardening, forging, brazing, etc. Frequencies of 50,000 to 1,000,000 cycles supplied by spark gap and vacuum tube oscillators are being used for surface hardening of irregular parts, where the contour must be followed closely. Frequencies from 1 to 30 megacycles with power up to 200 kW, supplied by vacuum tube oscilla-

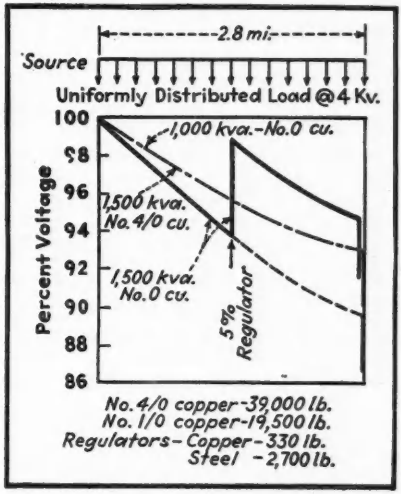

Fig. 15

tors are proving useful for dielectric heating, such as curing the glue in plywood and speeding up the processing of pieces formed from materials of high thermal resistivity.

Infra Red.

For radiant heating by infra-red special lamps have been developed, ranging from 250 to 1,000 watts, which have much longer life than incandescent lamps. A practical life of 5,000 hr. or longer can be obtained by operating at 2,500 K colour temperature. A new lamp operating at 2000 K gives only a cherry-red glow and practically no light output. Such lamps are particularly valuable for paint drying, especially if synthetic lacquers are used. Since oxydation and polymerization are involved in drying or curing of most organic finishes and as these are accelerated by ultra-violet, it has been suggested that the addition of ultra-violet radiation to infra-red would be useful in speeding the hardening of certain finishes. Actual tests, however, indicate that while this accelerates the top dry of air-dry materials, the advantages gained are more than offset by the wrinkling tendencies and the inferior "rough dry."

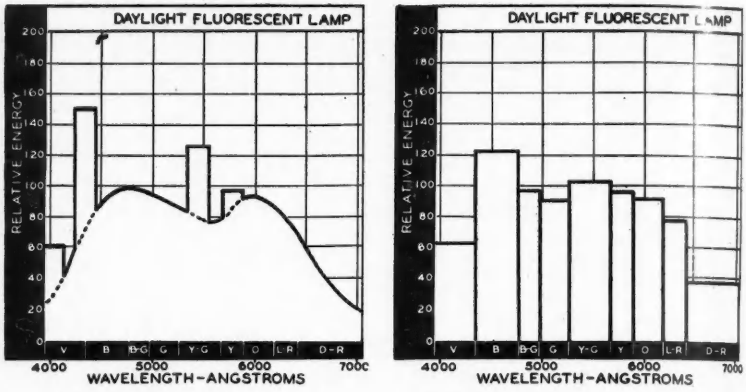

Fig. 16. A combination "bar" diagram and continuous curve (left) compared with the customary "bar" diagram (right) for a daylight fluorescent lamp.

Colour of Illuminants.

Introduction of fluorescent lighting has aroused interest in the effective use of these colours. A combination of a "bar" diagram for the mercury contribution with a continuous curve for the light from the phosphors was suggested as most satisfactory for intensity curves showing the spectral distribution of such light. *Fig.* 16 shows such a chart for the daylight fluorescent lamps compared with the customary bar diagram.

PROBLEMS IN AIRCRAFT STRUCTURAL RESEARCH

By F. R. SHANLEY, Chief Structural Engineer, Lockheed Aircraft Corporation, Burbank, Calif. (From *Mechanical Engineering*, Vol. 65, No. 3, March, 1943, pp. 169-178.)

(*Continued from p.* 151)

Joints and Fittings.

Joints have always been the weak links in most structures. Since it is impossible to make a riveted or bolted joint in sheet metal without reducing the cross-sectional area of the sheet, the structural efficiency of all parts of the structure critical in tension is governed by the efficiency of the joint itself. It would seem worth while to conduct a systematic investigation of tension joints in sheet metal, bringing together all available data and supplementing these by additional tests, if necessary.

Stress concentration and fatigue will always be an important pair of subjects for research. Photo-elastic methods have proved to be a powerful tool in understanding the flow of strain below the elastic limit. For members which are subjected to violent and rapid alternating stresses such methods are directly applicable, as the endurance limit will be relatively low, but there are few places in an aeroplane structure that will ever be subjected to such violent conditions. Hence, we need more knowledge of stress-concentration effects in the plastic range and more fatigue data representing occasional loadings of relatively high magnitude. The literature on fatigue has recently shown such a trend.

The photo-grid process may be of some use in determining the flow of strain beyond the elastic limit, if sufficient refinements can be made (22).

The full-scale testing of actual parts under impact loads appears to be the best way to obtain useful data on impact. At Lockheed we have constructed a very simple "pile driver" in which heavy weights can be dropped a distance of 29 ft. (Fig. 11). This machine enables us to break large specimens under conditions similar to those of actual service. The most recent tests have been on flash welds. A typical specimen, after testing, is shown in Fig. 12.

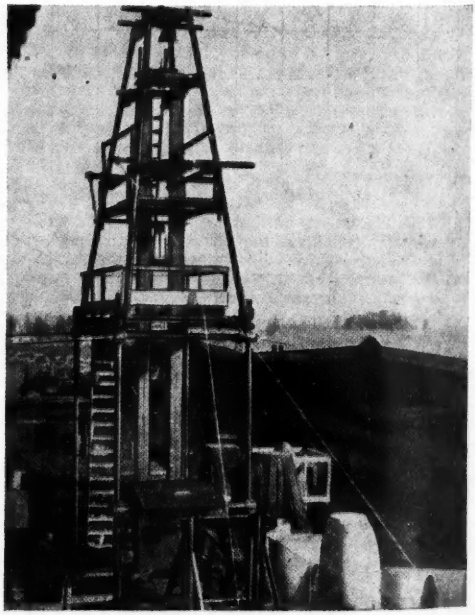

Fig. 11. "Pile-Driver" Impact-test Jig.

Fig. 12. Flash-welded specimen after impact test.

Structural Indexes.

Structural engineers seem to be slow in recognizing the usefulness of the principle of dimensional similarity. Perhaps this is because most writers on this subject emphasize the use of small-scale models, rather than the more general application of "structural indexes." Small-scale models are, of course, very useful and will become more important as the size of the aeroplane increases. The greatest obstacle to their use, to date, has been that any considerable reduction in scale will usually require sheet thickness that is too flimsy to be practical, rivets and screws that must be specially made, and other details which, taken together, often turn out to make the model at least as expensive as the full-sized specimen.

The real value of similarity principles lies in the fact that every structure actually represents an infinite family of structures, obtained by multiplying every dimension by a numerical factor. The strength, stiffness, and behaviour of every member of this family can be predicted without any further analysis or tests, if these characteristics are known for one member. Thus, if a certain structural component were expanded in every dimension by a factor of 2, the strength would increase four times. Furthermore, if the original structure happened to be the most efficient type for the particular conditions involved, the expanded structure would also represent the optimum type for the new conditions.

Since structural research is aimed primarily toward finding the optimum structure for the design conditions encountered, the application of this principle must be considered as an essential part of such research. Likewise, it should be possible to reduce the design and analysis time considerably by taking advantage of all the structures that have previously been designed and tested.

The key to the practical application of similarity principles is the use of a "structural index," or "coefficient." The structural index may be thought of as a factor describing the relationship between size and loading which is common to a whole family of dimensionally similar structures. Thus, if a designer wishes to know whether the properties of a certain shear beam, previously designed or tested, would be just right for some new application, he would compare the structural indexes for the two conditions. If they were the same, he could "design" the new beam simply by multiplying all dimensions of the old one by the proper factor.

For example, assume that a shear beam or truss had been designed to carry a shear load of 5,000 lb. and that the depth was 12″. The structural index would be, in this case, $S/h^2 = 5000/144 = 34.8$. Now assume that on a new design the depth available for the shear beam is 20″ and the shear load to be carried is 14,000 lb. The index could be $14{,}000/400 = 35$, which tells us that the new beam belongs to the same "family" as the old one. The dimensions of the new beam may, therefore, be determined by multiplying every dimension of the old one by the ratio 20/12. Since the strength goes up as the square of this factor, the new beam will have almost exactly the required strength. Furthermore, if the original beam had been very carefully designed and tested, to give maximum strength/weight efficiency, the new beam derived from it would represent the same degree of efficiency.

In actual practice the procedure would be to determine structural sizes and proportions on an "ideal" basis, ignoring available gauges, rivet sizes, etc. After the "ideal" structure has been determined for a particular case, it is a simple matter to convert to practical dimensions. This procedure also indicates the weight penalty involved in having to use a limited number of sheet gauges, etc.

The structural index is particularly useful in design work because it contains in it two things that the designer knows to start with. One of them is the intensity of the load, and the other is a dimension which limits the size of the structure. For shear beams, it is the shear load and the depth of the beam; for columns, the axial load and the length of the column; for circular shells in bending, the value of the bending moment and the diameter of the shell, and so on. In contrast, the "stress-analysis" type of coefficient (such as slenderness ratio for columns, or section modulus for beams) does not contain any measure of the loading condition; hence "cut-and-try" methods must be used in selecting sizes. Perhaps too much emphasis has been placed upon determining the strength of an existing structure and not enough on the selection of a structure for certain existing conditions.

Materials.

Which material is best? The facts are that there is really not a great deal of difference between various competitive materials, on a purely strength/weight basis. A clever designer can largely overcome the disadvantages of steel (mainly thinness) and can emphasize its advantages (spot-welding). Similarly, the corrosive tendencies of magnesium can be minimized by careful protection and good design, in order to take advantage of its lower density (greater thickness for the same weight). Even wood can still take its place along with the materials that pushed it out of the picture years ago, and, in fact, has been making considerable come-back recently because of critical material shortages.

The final decision as to the type of material to use will involve many factors, the most important of which will probably be production.

Under present conditions it would be disastrous for a large company to attempt a large-scale change-over in the basic materials of constructions. Every material has its peculiarities, extending down to such small matters as bend radii and the sharpening of drills. Countless hours of research and experimentation with details have been spent to "lick" the little every-day problems that can ruin the production line.

Improvement in the materials already being used is, however, of greatest importance. Anything that can be done to increase strength without seriously interfering with production will be incorporated in the design as soon as possible.

There is no question about the important part that reinforced plastics will play in the design of to-mcrrow's aeroplane. But the development of the plastic material is only a first step; the second step will be to work out all the design and production details, such as attachment methods, tooling, drilling holes, repairs, and similar practical items. In the author's opinion, we are about ready to enter this stage in the development of plastic structures.

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MOULDED PLASTIC-BONDED VENEERS AND WOOD IN AIRCRAFT PRODUCTION

By ROBERT J. NEBESAR, Chief Engineer, Universal Moulded Products Corporation, Bristol, Va. (From *Mechanical Engineering*, Vol. 65, No. 3, March, 1943, pp. 197-201.)

THE advantages of wood construction are well known and need not be discussed at any great length.

The most important factor is the strength-weight ratio. Since the weight in aircraft construction is of the utmost importance, it must be considered in relation to the strength. Thus we use the formula for comparing the ratio of strength to weight as given in Table I for tensile and compression values.

The values contained in Table I were established on the basis of three seconds duration of stress. Much higher stresses could be carried for shorter duration, as is the case in aircraft stressing where gusts, pull-up, or landing loads are of the magnitude of the fraction of one second duration. Furthermore, as aircraft structures are proved by static tests of considerably longer duration of loading, still greater margins of safety are obtained. The effect of duration of load on wood structures is shown in Fig. 1.

Even though seemingly slightly higher values could be obtained with special steels or some aluminium alloys for ultimate tensile strength to weight ratios, this slight advantage disappears by the necessity of having to make tension joints or connections. While in wood constructions, such as joints are mostly made by glueing, without any decrease in strength, in metal joints made by riveting or bolting, severe penalties are introduced in strength because of decreased sectional areas and stress concentrations. Of course, both joints increase weight to a limited extent.

For strength-weight ratios at yield point, the advantage is chiefly on the side of wood, which is an important factor so far as rigidity is concerned.

The block-compression strength-weight ratios are not especially favourable for wood. Since, however, the compressive strengths for most aeroplane structures are considered only as column or panel strengths where form factor is so important, the advantage again lies on the side of wood.

Since form factors depend mostly upon thickness which may be used for the same weight, and since higher thicknesses give greater rigidity, both of these

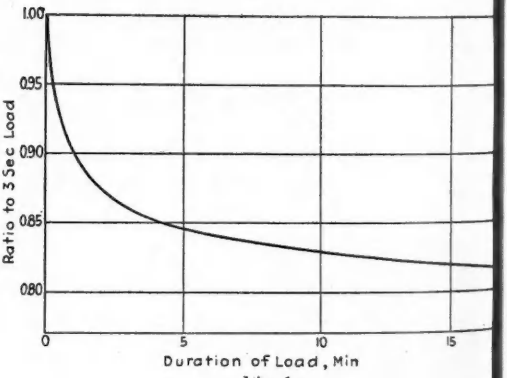

Fig. 1

TABLE I. Tensile and Compression Values of Various Materials.

Material	Birch	Hickory	Maple	Yellow Poplar	Spruce	Low-carbon steel 1025	Chrome-moly. ×4130	Nickel Steel	Aluminium 17ST	Aluminium 24ST
Unit weight, lb. per cu. in.	0.025	0.030	0.025	0.016	0.016	0.283	0.283	0.286	0.101	0.100
Ultimate tensile strength, p.s.i.	15,500	19,300	15,500	9,100	9,400	55,000	90,000	120,000	55,000	62,000
Elastic limit (tensile), p.s.i.	9,500	10,600	9,500	6,000	6,200	25,000	50,000	60,000	25,000	32,000
Ratio ultimate tensile strength/weight ..	608,800	654,000	608,800	561,700	580,200	194,300	318,000	419,600	544,600	620,000
Ratio elastic limit/weight	373,000	359,200	373,000	370,400	382,700	88,300	176,700	209,800	247,500	320,000
Compression strength (11 grain) wood ..	7,300	8,700	7,500	5,000	5,000	55,000	90,000	120,000	55,000	62,000
Ratio compression strength/weight ..	286,700	294,800	294,600	308,600	308,600	194,300	318,000	419,600	544,600	620,000

facts allow higher stresses to be reached before wrinkling or collapsing. Therefore, panels of greater length can be used for wood structures, thus saving in rib or stringer spacing, with consequent savings in both weight and labour.

However, in stressed-skin structures, these considerations are partially outweighed by the fact that centroids of cross-sectional areas in wood structures, due to greater sizes or thicknesses, are closer to the neutral axis.

Concentrated loads, such as those occurring at fittings of sub-assemblies, can easily be handled by laminated attachment blocks. Such construction, as shown in Fig. 2, provides for ample direct-load distribution to the skin and stringers without complicated fitting designs.

One of the most desirable features of wood construction is the admirably smooth skin, which stays smooth even under abnormal conditions, without wrinkling. This greatly increases the speed of aircraft.

Overcoming Objections to Use of Wood in Aircraft Construction.

The more serious objections to the use of wood in aircraft construction, which have been raised periodically since the beginning of this art, are as follows :—

1. Difficulties were early experienced with vegetable and animal glues, particularly in relation to their durability, or stability, under varying atmospheric conditions. Dimensional and strength variations with time were also involved.

Such problems were solved with the development of waterproof and boilproof synthetic-resin glues. Two basic types are being used as follows :—

Hot-Press Synthetic Resin.

Such bonding agents are used at present in the moulding process and in the manufacture of plywood. Different types have been developed, the principal ones being phenolics and urea formaldehydes. Both demand careful control in mixing the glue, spreading, and some control of humidity and temperature conditions.

As an example of such operations, the following are the requirements for the urea-formaldehyde thermo-setting resin, known commercially as Plakson 700-2 :—

This hot-press glue may be spread within four hours after mixing at ordinary temperatures. The weight of the wet glue line may vary from 20 to 40 lb. per 1000 sq. ft., depending upon the application intended. The assembly or lay-up time is much greater than allowed for spreading. Fig. 3 shows the estimated maximum permissible assembly time versus temperature. On the same curve the actual working range used by the author's Company is indicated by the shaded area in the lower corner of the graph which indicates the increased safety. It should be noted that the assembly time is defined as the time elapsed between spreading and the application of pressure and heat to form a bond.

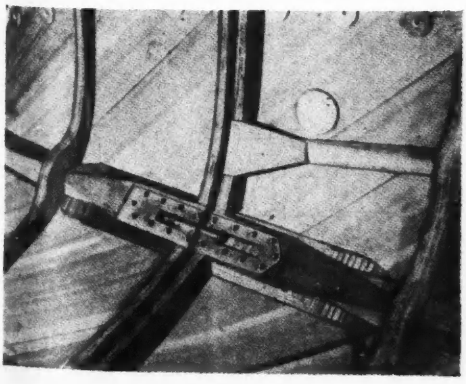

Fig. 2.

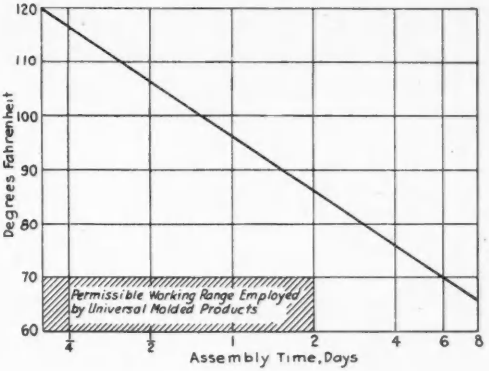

Fig. 3.

Cold-Press Synthetic Resin.

These serve mainly in assembly work where moulding cannot be used. Here again we will give an example of using the widely recognized urea-formaldehyde thermo-setting glue, Plaskon 250.

Plaskon 250 is mixed in quantities of 6 to 10 lb. at a time and stored in a refrigerated compartment. The glue is then distributed in paper cups as needed to the various shops. Fresh glue is mixed every 2½ hours throughout the working day, and all unused glue is discarded at the end of each 2½ hours period. Inert dyes of various colours are mixed with the cold glue as a means of distinguishing the status of the glue with respect to its permissible period of utilization. Actually the glue handling procedure outlined is conservative, as such glue is reasonably safe to use as long as it is in condition to spread. By keeping each individual glue cup on ice, the pot life may be extended to about 12 hours.

Cold-press glue is allowed an assembly or lay-up time of only 15 minutes—that is, the pressure should be applied within 15 minutes after spreading. The weight of wet-glue line recommended for this type of glue varies from 35 to 40 lb. per 1000 sq. ft.

Both of these basic types of glues are stable for any extreme atmospheric conditions for many years.

2. Difficulties have been experienced in connection with the necessary interchangeability for mass production, especially for aerodynamically improved designs, involving complicated shapes and forms with complex composite double curvatures.

Considerable improvement has been made in this situation by a great advance in moulding techniques.

Moulding is essentially a process in which a bond is made between two pieces of wood, wood veneer, or other materials by means of applying fluid pressure and heat of the proper magnitudes through time intervals required to cure the particular bonding agent employed.

The moulding process is utilized principally in the manufacture of flat plywood for general use and shape plastic-bonded veneer structures of composite curvatures for specific uses. For most such shaped structures, other structural components such as frames, pads and stringers are moulded integrally with the plywood shell in one operation. This particular feature falls under the Vidal patents.

Detailed steps of moulding process include :—

(*a*) Spreading glue on the veneer and/or other pieces to be joined. This is accomplished by glue-spreading machines of different makes and different sheet-width capacities. Veneer which has been edge-glued to form sheets of larger sizes is thus limited as to sheet size by the glue-spreader width. Ordinarily, this restriction is of no significance in manufacturing shaped or curved shell for, in such cases, the veneer must be laid or wrapped in relatively narrow strips. It has been found that applying a double spread—that is, on both surfaces to be glued together—is superior to the single-spread method. For the components which cannot be accommodated by glue-spreading machines, the glue is spread by brush.

(*b*) Veneer-laying or wrapping is, as implied, simply forming the veneer to the mandrel or caul board on which the plywood component is to be shaped. If stringers, frames, pads, etc., are to be moulded to the plywood shell, as is done under the Vidal patents, such parts are inserted in snug-fitting recesses in the mandrel prior to the veneer-wrapping operation. Inserted parts are machined to come approximately just a little over, being flush with the surface of the mandrel. Upon completion of moulding cycle, the inserted parts are bonded to the plywood shell to form an integral part of the structure. In wrapping veneer, the various strips are temporarily secured to the mandrel and to each other by staples. Hand-stapling machines are used for this operation. In view of the fact that the mandrels used in the moulding process are made of wood, it is necessary to treat their surfaces to prevent bonding between the mandrel and the moulded parts in locations where the adhesive can squeeze out. Acetate dope, or sometimes cellophane paper, have been found to be satisfactory for this purpose.

While with the Vidal patents mostly male-form mandrels are used, in the Duramold process the moulding is done for skins only, using female mandrels, so that the outside of the skin will be as smooth as possible.

(*c*) The actual moulding or cooking is done principally in autoclaves or pneumatic presses.

The autoclave used is fundamentally a large tank with a pressure-tight hinged end of heavy construction. After the veneer has been laid or wrapped on a mandrel, the mandrel is enclosed in a fluid-tight rubber bag and the whole is moved into the autoclave on a small car. The end door of the autoclave is then closed and secured. Hot water and compressed air are admitted to the autoclave to furnish the heat and pressure necessary to set the synthetic-resin bonding agent. The compressed air affords enough pressure to allow the temperature of the water to be raised beyond the normal boiling point without converting to steam. In the proper combinations the hot water and compressed air give the desired moulding temperatures and pressures. The minimum moulding conditions permitted are 50 p.s.i. pressure and/or 210° F. temperature. It has been found desirable to apply full pressure to the autoclave within four minutes after the tank temperature reaches 120° F.

The time required to mould any given part is a function of the rate of heat penetration through the part. A rule of thumb employed for timing a " cook " in these instances where the thickness of the wood is appreciable is one hour per inch thickness of wood. This rule applies to the usual case where heat is conducted into the work from one side at a much greater rate than the other. Such conditions arise from the fact that on one side the work being moulded is separated from the water in the autoclave only by the thickness of the rubber bag in which the work is enclosed, whereas heat transfer from the other side must take place through the bag and the mandrel or platen.

A successful steam-air cooking process has also been developed. In this process steam and air supplant the water as a source of heat and pressure. Compressed air is used, however, as a supplementary pressure medium to provide flexibility in the pressure-temperature combinations required.

Pneumatic pressure of two types are used in addition to autoclaves for moulding smaller parts. As in the autoclave, heat and pressure are furnished by steam and compressed air. For the production of small parts, pneumatic presses are very satisfactory because of the rapidity with which they can be loaded and unloaded.

At present the use of cold glue is essential to the moulding processes. Practically all aircraft structural components of any size are moulded in halves to facilitate removal from the mandrels. Cold-glue operations are employed to assemble such structures. It might also be said, with some reservation, that in all assembly work cold-glue processes are employed.

Since all assembly work is done with cold glue, which itself requires perfect humidity and heat control within fairly close limits, it is here that interchangeability is achieved. Moisture content of wood is kept between allowable limits, thus preventing undesirable dimensional changes during fabrication. Of course, all dimensional wood must be properly kiln-dried.

To prevent changes after fabrication and when the structure is in service, different finishes are being used.

3. Problems are involved in providing aircraft structures of veneers and wood which will be durable under all weather and climatic conditions.

The most durable finish is achieved by covering all exterior surfaces by light-weight fabric, such as balloon cloth, which is doped on the surfaces over a special coat of sealer. Several other coats are applied over the fabric which gives the finish the required flexibility and elasticity, while the finishing coats and paint give the all-weatherproof durable finish.

Several types of other finish procedures have been developed, giving more or less adequate degrees of protection. For fabricless-type finishes, it is important to seal exposed end-grain surfaces with proper sealer compounds and to protect them with additional fabric tape. The interiors of the surfaces are finished usually by several coats of phenol-formaldehyde-derivative sealers.

4. Finally there is the problem of weight control.

As weight control is most necessary in aircraft construction, the variation in specific gravity of all types

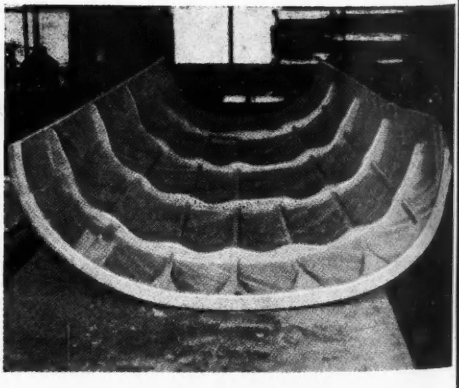

Fig. 4.

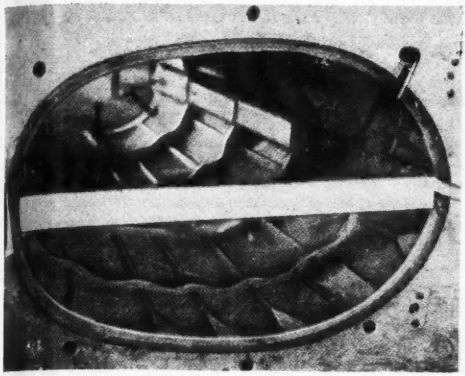

Fig. 5.

Fig. 7.

of wood species must be given proper consideration. Fortunately it can be stated that the strength properties of woods vary either in direct ratio to the specific gravity or even more rapidly, that is, with higher powers.

Existing strength data are, therefore, based upon the minimum values of specific gravity of species; and for weight calculations, somewhat higher values of specific gravity are used.

However, in the case of wood in general and for some species in particular, the range of specific gravity is very wide, which would affect the weight to a greater extent than is generally recognized.

This difficulty can, of course, be overcome by proper specifications and control. In some instances, it has been thought necessary to specify also the upper limits of specific gravity for some species.

Examples of Production.

Some examples of moulded plastic-bonded veneer and woods are presented.

Semi-monocoque Fuselage.—The aft section of the XBT-16 fuselage is a semi-monocoque moulded-plywood construction. In Fig. 4 the moulded half of the fuselage is shown as it looks after the moulding operation. The spruce longitudinal stringers are standard sections, produced by the author's Company, and the frames are of laminated mahogany. Birch plywood is used in small quantities, principally for reinforcing material. The skin for the fuselage is two-ply poplar with the grain at 45° to the longitudinal axis of the fuselage. In the extreme end base of this fuselage, an additional ply is added to the skin for stiffness.

The two halves are assembled in the envelope-assembly jig shown in Fig. 5.

A cold-glue operation is employed to join the halves by apron-string. With the installation of fittings and accessories, and after proper finish and painting, the fuselage is complete for final assembly.

Wing Outer Panels.—The wing outer panels of the XBT-16 aeroplane are of two-spar skin-stressed construction. While the basic structural type is conventional, the execution of the detailed construction features sets the structure apart from the conventional category.

The wing outer-panel section with the front portion of the moulded nose skin is shown in Fig. 6.

The outer-panel wing front spar, an I-section, is constructed of birch-plywood web and laminated-hickory flange materials. Spruce flanges, moulded to a Z-section, form the outer-panel rear spar.

Ribs are attached to the spar webs by standard plywood angles. Apron strings and moulded skins themselves complete the tie-tin structure for the rib-to-spar connections. The intermediate ribs are of the truss type, and the nose ribs are of the web type.

Wing Tips.—Removable wing tips are constructed of birch-plywood skin with spruce stringers, laminated-spruce bow, and birch- and poplar-plywood reinforcements. The skins are moulded in halves integral with the stringers, and half of the bow end with birch reinforcing pad through which the attachment-strip bolts pass. In Fig. 7 a half wing-tip mandrel is shown routed and fitted with stringers and attachment pad. Cold-glue operations are used to assemble the two wing-tip halves and to secure a few small gussets.

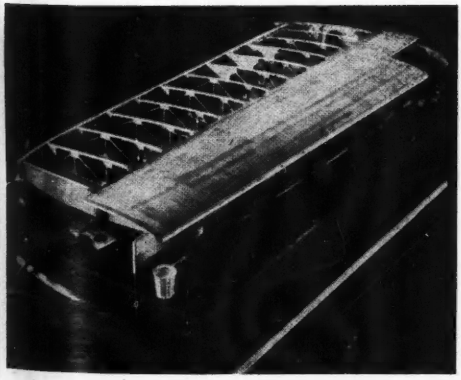

Fig. 6.

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THE OCCURRENCE of THE PHENOMENON of AGEING in CAST IRON

By EUGEN PIWOWARSKY, Aachen. (From *Die Giesserei*, Vol. 29, No. 21, October, 1942, p. 358.)

MANY technical alloys, both of ferrous or non-ferrous base, are subject to change of properties on ageing, a phenomenon which was first observed and studied on duralumin and copper-aluminium alloys. This ageing is nowadays ascribed to alterations in the arrangement of the crystal lattice.

In the case of pure iron and irons low in carbon the presence of the elements carbon, silicon, nickel, copper, phosphorus, titanium or molybdenum make the metal particularly susceptible to changes on ageing.

With regard to cast iron systematic research has not been completed, but E. Piwowarsky and others believe an otherwise inexplicable brittleness met with in cast iron to be due to ageing. This brittleness is most noticeable in cast irons containing copper, nickel, chromium, antimony, molybdenum and titanium.

E. Piwowarsky, of the Technical High School, Aachen, has recently investigated the subject as follows :—

The material chosen was an industrial thin-walled special cast iron containing 3.6% carbon, 2.6% silicon and 0.75% phosphorus, which showed a tendency to develop brittleness. Separate portions of this iron were heated to temperatures ranging from 250–550°, kept at the temperature for 20 minutes, and chilled in water. Each sample was subjected to the Rockwell B test for hardness after periods of 20, 40, 120 and 160 hours.

Fig. 1 (the ageing of grey cast) shows that, although the actual increase in hardness was small, the curve corresponds to the ageing curves of other alloys. It was found that at 160 hours the maximum change had occurred.

It is probable that small amounts of copper, either alone or in conjunction with other elements, are the main factor responsible for age changes, and researches in this direction may demonstrate its extreme importance in the practice of grey iron casting.

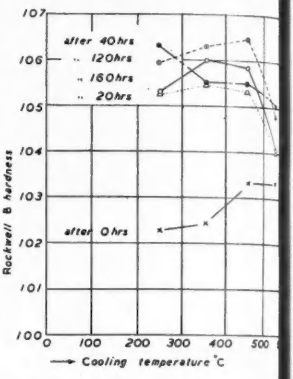


Fig. 1.

ACCURACY OF MOULDED THREADS IN PLASTIC MATERIAL

By K. MEHDORN, Essen. (From *Kunstoffe*, Vol. 32, No. 4, April, 1943, pp. 113-124.)

IT is very difficult to produce moulded threads to the standard tolerances of metallic screws and nuts. The moulded threads would not pass standard (metallic) thread gauges. There is a discrepancy between user and producer. The following considerations may give some information.

In the following, moulded threads only are to be discussed; with tapped threads, the conditions regarding accuracy are identical with those of metallic material. As basic threads, the metric types are considered, but the same principles and considerations may be applied for any thread system. Substantial difficulties arise with moulded threads. Up to recent years a not too loose fit between mating parts and an interchangeability only was required; and by a certain skill in the tool-making, the moulder met the requirements. Some moulders went further, taking into account the shrinkage of the material in axial and radial direction, but it became clear that it was very difficult or sometimes impossible to work according to standard metallic thread tolerances (DIN 2244, 13, 14). The wide application of moulded threads has not cleared the conditions, as the users have not insisted on applying the standard tolerances.

The standard metric thread system has been revised and simplified in the last two years, without interfering with the interchangeability of the existing metric system. The specific items for each thread system are the five items :—

Top diameter ..	d (Bolt)	D (Nut)
Core diameter ..	d_1 (Bolt)	D_1 (Nut)
Effective diameter ..	d_2 (Bolt)	D_2 (Nut)
Pitch	h	
Angle of thread ..	v	

The tolerances are not influenced by the variations of the first two items, but the strength of the thread depends on them. The lower limit for strength is to provide a depth of thread not less than 60% (in extreme cases 50%) (for metallic screws). There are other conditions with plastic materials owing to the different strength properties. Experiments have shown that the critical length of engagement lies .4d with metallic screws and metallic nuts, but 1.5d with plastic nuts, i.e., with threads in plastic material. The experiments were carried out with threads of 60% depth and of standard metric type.

For the following considerations a depth of 50–60% is assumed, as provided in the last DIN standard, thereby the minimum for bolt-top diameter and the maximum for nut core diameter is fixed.

The accuracy of the screws is also affected by the tolerances and especially by the pitch tolerances. According to the new standard (DIN 2244) the length of the "Go" gauge is basically identical with the length of the threaded hole, and the allowance for too long holes is determined according to Standard Specification, and it is permissible to use gauges from the other class, i.e., with the length of the hole, the total tolerance of the effective diameter also varies. The pitch tolerance being only one part of the total tolerance (incorporated in the effective diameter tolerances), it is obvious that the pitch tolerances do not increase in linear proportion with the length of thread. The pitch tolerance being based on the diameter, it is clear that in plastic material with moulded threads, the pitch error will be increased owing to the shrinkage—which occurs in all directions, i.e., the pitch error in moulded plastics thread varies not only according to the length of thread, but is also influenced by the diameter of thread respectively, and by the numerical size of the thread. With larger dimensions, the shrinkage and the possibility of error increases.

Some of the leading moulding firms make great efforts in order to correct the shrinkage in axial and radial direction. The basic corrections are :—

Nut.

(1) *Diameter.*—The maximum of shrinkage (s_{max}) must be calculated. With the minimum shrinkage (s_{min}) any error could not be excluded. The resulting error "a" is a plus tolerance and numerical size,

$$a = (s_{max} - s_{min})\, d.$$

(2) *Length of Thread (pitch).*—The proper correction is to calculate with the average shrinkage s_{av}.

The unavoidable pitch error :—

$$b = (s_{max} - s_{av}) \times \sqrt{3} \text{ . n.d.}$$

To avoid jamming, the nut diameter is also increased by this additional figure :—

n.d. = length of thread, expressed as a multiple (n) of the diameter.

(3) Supposing the pitch correction is neglected (a method which cannot be recommended, not even for the shortest thread), in this case, the error :—

$$c = s_{max} \times \sqrt{3} \text{ . n.d.}$$

the total shrinkage error is therefore :—

Pitch + diameter correction (complete correction):

$$a + b = (s_{max} - s_{min})\, d + \sqrt{3} \text{ . n.d. } (s_{max} - s_{av})$$

and with diameter correction only (incomplete correction) :—

$$a + c = (s_{max} - s_{min})\, d + \sqrt{3} \text{ . n.d. } s_{max}$$

($\sqrt{3}$ n.d.s. = the length shrinkage acting upon the effective diameter, by metric thread, $\text{tg } 60° = \sqrt{3}$).

Bolt.

The conditions are identical as shown for the nut.

Shrinkage.—The figures for shrinkage, collected from catalogues, experimental work, etc., show very large fluctuations. It is impossible to work with commercial shrinkage figures in order to achieve the best results to approach or keep standard tolerances.

It is technically possible to obtain moulding powder with *limited* shrinkage fluctuations.

The comparative shrinkage figures are :—

TABLE I.

Phenolic-Cresolic Powder	Commercial Shrinkage			Limited Shrinkage		
Filler	Value %	s_{max} %	% deviation in shrinkage	Value %	s_{max} %	% deviation in shrinkage
Wood flour	.65 ± .35	1	± .35	.8 ± .15	.95	± .15
Cotton ..	.5 ± .2	.7	± .2	.6 ± .1	.7	± .1
Cellulose ..	.4 ± .2	.6	± .2	.4 ± .1	.5	± .1
Mineral ..	.3 ± .15	.45	± .15	.28 ± .05	.33	± .05

In the following discussion both shrinkages are considered :—

Supposed Difficulties in the Pitch-Shrinkage.—The main difficulties lie in the assumption that in tool-making it is very troublesome to obtain and work with the necessary number of gears to make appropriate allowances in cutting each thread, or it is difficult if not impossible to calculate according to the shrinkage figures.

In Table II a few selections are shown for the nominal shrinkage from .2% up to 1%. The selection of the gears shows corresponding results or figures with approximate value within useful limits.

Accuracy in Tool-making and Tool-wear.—It must be assumed that the tools for thread mouldings are to be manufactured with the same accuracy as the thread gauges. Furthermore, it is assumed that the threaded tool parts are ground after hardening. If this is not the case, the whole tolerance may be consumed by distortion during hardening.

For the tool-wear, double the amount of the permissible gauge wear (Standard Specifications) has been assumed.

It must be stated that to base the accuracy and tool-wear on the figures as fixed in the standards is rather disadvantageous for the moulding industry, because the average tool-making plants are not equipped accordingly.

TABLE II. Gear Selections to correct the pitch error.

Nominal Shrinkage %	Ratio	Selection	Correction
1.0	$\frac{1010}{1000} = \frac{101}{100}$		1.0
0.9	$\frac{1009}{1000} \quad \frac{1009.2}{1000} = \frac{5046}{5000} \quad \frac{6 \times 29 \times 29}{5000} = \frac{87 \times 29}{50 \times 50}$		0.92
0.8	$\frac{1008}{1000} = \frac{126}{125}$		0.8
0.75	$\frac{10075}{1000} \quad \frac{2015}{2000} = \frac{5 \times 13 \times 31}{2000} = \frac{65 \times 31}{40 \times 50}$		0.75
0.7	$\frac{1007}{1000} \quad \frac{1005.993}{999} \quad \frac{1006.2}{999} \quad \frac{5031}{4995} \quad \frac{559}{555} = \frac{65 \times 43}{73 \times 37}$		0.73
0.6	$\frac{1006}{1000} \quad \frac{1006.2}{1000} = \frac{5031}{5000} \quad \frac{9 \times 13 \times 43}{5000} = \frac{117 \times 43}{50 \times 100}$		0.62
0.5	$\frac{1005}{1000} \quad \frac{2010}{2000} = \frac{30 \times 67}{40 \times 50}$		0.5
0.4	$\frac{1004}{1000} \quad \frac{1002.996}{999} \quad \frac{1003.2}{999} \quad \frac{5016}{4995} = \frac{66 \times 76}{44 \times 11}$		0.42
0.3	$\frac{1003}{1000} \quad \frac{1002.8}{1000} \quad \frac{5014}{5000} = \frac{109 \times 46}{125 \times 40} = \frac{109 \times 115}{125 \times 100}$		0.28
0.2	$\frac{1002}{1000} \quad \frac{6 \times 167}{1000} = \frac{60 \times 167}{100 \times 100}$		0.2

Permissible tolerances for tool-accuracy and tool-wear are :—

TABLE III.

Nominal Diameter mm. Metric Thread	Tolerance for Coarse and Middle Class In thousands of mm.
.8 to 1.7	42
2 to 5.5	50
6 to 11	56
11.5 to 33	60
34 to 80	70
82 to 200	80
202 to 500	90

It is recommended to give full consideration to the shape of the threaded tool parts. The crest especially is to be made as sharp as possible perhaps above the theoretical profile, making use of full tolerances of the effective diameter, the object being to avoid jamming in crest and root after wear. But it is not recommended to increase these portions above the standard sizes.

Summary of Errors in Relation to Standard Tolerances.

Taking into account all tolerances due to the shrinkage, tool-making errors and tool wear (as discussed above), and comparing the results with the standard tolerances, it can be stated :—

With small diameters the length of engagement 3d must be accounted for, and with moulding powder of commercial shrinkages the results are very unsatisfactory. The threads moulded from general purpose powder are entirely out of the limits. Other powders, especially mineral-filled, are slightly better and within the limits for standard coarse tolerances—due to the lower shrinkage fluctuations of those materials.

The results are better with limited shrinkage fluctuations (according to the shrinkage figures shown on table).

The possibilities of moulding threads with these shrinkage figures may be stated as follows :—

With general purpose powder and coarse standard tolerances, it is possible to produce threads :—

Diameter up to M20..Length of engagement 1.25–3.15d
" " M42.. " " .5 –1.25d
" " M48.. " " .2 – .5 d

The sizes above up to 150 nominal diameter cannot be moulded according to standard tolerances.

The conditions are more convenient with cotton and cellulose filled powders, but only with mineral-filled materials is it possible to obtain moulded threads within standard coarse tolerances covering nearly all nominal sizes. This is valid, of course, only under careful tool-making, powder-making, and moulding. Errors due to warping, distortion after moulding, etc., are not allowed for.

The above conclusions show the moulding possibilities in a rather advantageous position compared with actual production. It was supposed that the tool-making facilities are working with an accuracy as required by gauge-making, therefore giving a favourable impression of the accuracy of moulded threads.

SUMMARY.

Suppositions.

(1) Careful accuracy in the tool-making with the limits as fixed on standards for gauges. If there are no proper tool-making facilities, it is better to get the threaded tool parts from an outside supplier.

(2) Fixed margin for tool wear. It is suggested double the amount of the standardized gauge-wear allowance. Sharp profile for thread (crest) is recommended.

(3) Fuctuation of powder-shrinkage must be kept within the limits :—

General purpose powder	±.15%
Cotton and cellulose filled powder..	±.10%
Mineral-filled powder	±.05%

(4) By fixing the tool dimensions the shrinkage in axial and radial direction (complete correction) must be considered.

The most important error is due to the shrinkage fiuctuations, and it is recommended to use powders with low-shrinkage co-efficients where possible.

Result.

With general purpose powder (wood filler) threads according to coarse tolerance standards and a few sizes only can be produced.

With cotton and cellulose filled powders more sizes may be moulded within coarse standard tolerances.

The best results are obtained with mineral-filled powders.

Deductions.

There is very little research work on moulded threads. It appears that this work has to be extended on :—

Accuracy of moulded threads in different moulding plants according to different tool-making facilities.
Research on tool wear.
Influence of accuracy on the strength of moulded threads.
Distortion after hardening on different steel types.
Distortion and warping on threaded parts; and, last but not least—
The improvement of the shrinkage fluctuations on moulded powders.

A HYDRAULIC RAM WORKING ON WAVE PROPAGATION

Invented by Prof. Dr. G. EICHELBERG, of the Federal Technical College, Zurich. (From *Schweizerische Bauzeitung*, Vol. 120, No. 17, 24th October, 1942, pp. 191-193.)

(*Continued from page* 155).

NOTE ON THE EICHELBERG RAM.

An acoustic wave of velocity a travels along the pipe of length l, containing fluid of density ρ, in the time $T = \frac{l}{a}$

To make it quite clear how in Scheme II, with its period of 4T, the pressure $p_{(x,\,t)}$ and the velocity $v_{(x,\,t)}$ vary with the distance x, measured from the left end A of the pipe length [o, l], and with the time t measured in the interval [o, 4T], let us neglect the time momentarily required for the sudden changes in the end conditions and consider two linear functions of p and v, namely,

$$\phi = \tfrac{1}{2}(v + \frac{p}{\rho a})$$

$$\text{and } \psi = \tfrac{1}{2}(v - \frac{p}{\rho a}) \quad .. \quad .. \quad .. \quad (1)$$

ϕ is constant to an imaginary observer moving with the velocity of sound towards the right, which is the positive direction of x and v; and ψ is constant to an observer moving to the left at the same speed. (See article by K. H. Grossmann: "The Analysis of Pressure Injection in Diesel Engines," *Schweizer-Bauzeitung*, Vol. 112, 1938, p. 249.)

This means that in the plane of x, t

ϕ is constant along the straight lines $x - at = \text{constant}$.

ψ is constant along the straight lines $x + at = \text{constant}$.

Therefore, the functions $\phi_{(x,\,t)}$ and $\psi_{(x,\,t)}$, plotted at right angles to the x, t plane against $o \leq x \leq l$ and $o \leq t \leq 4T$, are cylinders generated parallel to the various groups of straight lines, their values being determined from the end conditions.

Thus $v_{(x,\,o)} = 0$, and $p_{(x,\,o)} = p_{min} = 1$ atmos., giving

$$\phi_{(x,\,o)} = \frac{p_{min}}{2\rho a} = \phi_o$$

$$\text{and } \psi_{(x,\,o)} = \frac{-p_{min}}{2\rho a} = \psi_o = -\phi_o \ldots\ldots (o < x \leq l) \quad ..(2)$$

Therefore, for the interval T (Fig. 1),

$$\phi_{(l,\,t)} = \phi_o \ldots\ldots (o \leq t < T) \quad .. \quad (3a)$$

$$\text{and } \psi_{(l,\,t)} = \psi_o \ldots\ldots (o < t \leq T) \quad .. \quad (3b)$$

During the interval [o, 2T], the left end A of the pipe is connected to the vessel of intermediate pressure $p_M = 5$ atmos. The right end B is closed during the interval [O, T], and is connected to the high pressure vessel of $p_H = 7$ atmos. during the interval (T, 3T).

Therefore,

$$p_{(o,\,t)} = p_M \ldots\ldots (o \leq t < 2T) \quad .. \quad (4)$$

$$v_{(l,\,t)} = O \ldots\ldots (o \leq t < T) \quad .. \quad (5)$$

$$p_{(l,\,t)} = p_H \ldots\ldots (T \leq t < 3T) \quad .. \quad (6)$$

$$\text{Since } v = \phi + \psi \text{ and } p = \rho a(\phi - \psi) \quad .. \quad (7)$$

then, from (5) and (3a),

$$\psi_{(l,\,t)} = v_{(l,\,t)} - \phi_{(l,\,t)} = -\phi_o = \psi_o \ldots\ldots (o \leq t < T) \quad .. \quad (8)$$

Therefore, at A, ψ_o is constant not only during the interval [O, T] as stated in (3b) but for twice as long, so that

$$\psi(o, t) = \psi_o \ldots\ldots (o < t < 2T) \quad .. \quad (9)$$

From (9), (4) and (2)

$$\phi(o, t) = \frac{p(o, t)}{\rho a} + \psi(o, t) = \frac{1}{\rho a}\left(p_M - \frac{p_{min}}{2}\right) = \phi_1$$
$$(o < t < 2T) \quad .. \quad .. \quad (10)$$

Therefore,

$$\phi(l, t) = \phi_1 \ldots\ldots (T < t < 3T) \quad .. \quad (11)$$

This, with (6) and (10), gives

$$\psi(l, t) = \phi(l, t) - \frac{p(l, t)}{\rho a}$$
$$= -\frac{1}{\rho a}\left(p_H - p_M + \frac{p_{min}}{2}\right)$$
$$= \psi_1 \ldots\ldots (T < t < 3T) \quad .. \quad (12)$$

Therefore,

$$\psi(o, t) = \psi_1 \ldots\ldots (2T < t < 3T) \quad .. \quad (13)$$

Since, in the interval [2T, 4T], A is switched over to the low pressure vessel, where $p_N = 3$ atmos.

$$p(o, t) = p_N \ldots\ldots (3T \leq t < 4T) \quad .. \quad (14)$$

and we get, from (12) and (13),

$$\phi(o, t) = \psi(o, t) + \frac{p(o, t)}{\rho a}$$
$$= \frac{1}{\rho a}\left(p_H - p_M - p_N + \frac{p_{min}}{2}\right)$$
$$(2T < t < 4T)$$

By making $p_{min} = p_M + p_N - p_H$ .. .. (15)

we get (see Equation 2),

$$\phi(o, t) = \frac{p_{min}}{2\rho a} = \phi_o \ldots\ldots (2T < t < 4T) \quad .. \quad (16)$$

Therefore, $\phi(l, t) = \phi_o \ldots\ldots\ldots (3T < t \leq 4T)$ .. (17)

and, since B is closed again at time 3T,

then $v(l, t) = 0 \ldots\ldots\ldots (3T \leq t \leq 4T)$ .. (18)

Therefore,

$$\psi(l, t) = v(l, t) - \phi(l, t) = -\phi_o$$
$$= \psi_o \ldots\ldots\ldots (3T < t \leq 4T) \quad .. \quad (19)$$

Equations (16) and (19) show that the initial conditions are restored at time 4T. Thus,

$\phi(x, 4T) = \phi_o$ and $\psi(x, 4T) = \psi_o \ldots\ldots (o < x \leq l)$ .. (20)

and so the cycle can begin anew.

In Fig. 1, which illustrates the functions $\rho a\phi$ and $\rho a\psi$, the area $o \leq x \leq l$, $o \leq t \leq 4T$ is divided into four equal spaces of length T on the time axis. In regions I and III, ψ is constant, while in II and IV ϕ is constant. Hence, by equation (7), in the first and third regions, the functions ρav and ρ differ from $\rho a\phi$ only by a constant ($\pm \rho a\psi$); while, in the second and fourth they differ from $\pm \rho a\psi$ by the constant $\rho a\phi$. Consequently, the operating conditions adopted by Eichelberg give to p and v the characters of ϕ and ψ, i.e., of waves that go to the right and to the left, travelling along the pipe with the velocity of sound and being reflected at the right end and at the left alternately. Fig. 2, derived from Fig. 1, and equation (7), exhibits the functions $p(x, t)$ and $\rho av(x, t)$, the dotted lines representing the diagrams in Fig. 8 of the article to which this note is attached. This figure demonstrates that, in the regions discussed, both p and v are constant along the straight lines x—at = constant and x+at = constant, in turn.

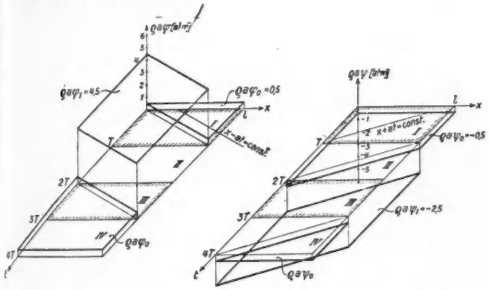


Fig. 1. Perspective diagram of the functions $\rho a\phi(x, t)$ and $\rho a\psi(x, t)$

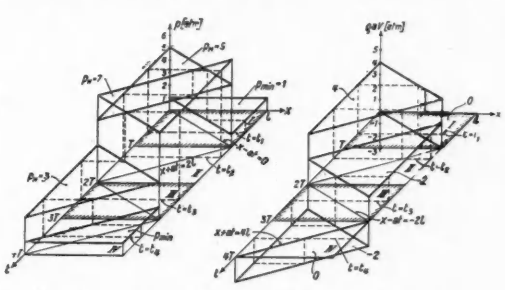


Fig. 2. Perspective diagram of the functions $p(x, t)$ and $\rho av(x, t)$

ALUMINIUM IN ELECTRICAL ENGINEERING

By F. STREIFF. (From *Brown Boveri Review*, Vol. 29, April, 1942, No. 4, pp. 87-95.)

GREAT prejudice is encountered in practice against the utilization of aluminium for electrical constructions. Aluminium is a relatively newcomer among the metals and this applies more especially so to its alloys which have only been exhaustively investigated and subjected to practical tests within very recent years. It is generally forgotten that there have been transformers built which are completely wound with aluminium or having aluminium leads, motors with aluminium windings which, built at the time of the last World War, are running satisfactorily to-day. The Eglisau power station finished in 1919/20 has Al cables from the generator terminals outwards and bus-bars in the switchgear plant made of that metal and no trouble has occurred on this account. The following guiding principles are important to ensure the successful utilization of aluminium and its alloys in electrical engineering :

1. The designer must know the mechanical, electrical, physical and chemical properties of this material as well as the possibilities it offers for working and machining.

2. The shops must develop methods of working this material and must be equipped to that end.

3. All knowledge gained in practice must be collected, subjected to critical examinations and then distributed for the benefit of all interested parties.

Fundamentally, a distinction is made between malleable alloys and those which are suitable for casting. Brown Boveri have laid down standardization rules for their own uses which cover the mechanical and electrical properties of aluminium and those alloys

which are useful in electrical and other constructions. These rules completed by much data on physical and chemical properties and information on how the material can be worked, allow the designer to choose the material best suited to his purpose. As regards the alloys, a certain discrimination was exercised, which led to the elimination of certain Al-Cu alloys which were too sensitive to corrosive action.

If two metals of different electrolytic potentials are in continuous contact under a constant supply of moisture we get what is termed contact corrosion. The metal of low electrolytic potential is destroyed by the one of higher potential.

Electrolytic voltage scale referred to hydrogen. The left column is valid for pure metals and the right column for technically worked metals. Here non oxidized aluminium attains about the same potential as zinc.

		Voltage difference referred to oxidized Al ≒ zinc
Magnesium	— 1.8 volts	
Aluminium	— 1.45 „	
Manganese	— 1.1 „	
Zinc	— 0.77 „	0 volts
Chromium	— 0.56 „	0.12 „
Iron	— 0.43 „	0.25 „
Cadmium	— 0.42 „	0.26 „
Cobalt	— 0.23 „	0.45 „
Nickel	— 0.20 „	0.48 „
Tin	— 0.146 „	0.534 „
Lead	— 0.132 „	0.548 „
Hydrogen	0 „	0.68 „
Copper	+ 0.35 „	1.03 „
Silver	+ 0.80 „	1.48 „
Mercury	+ 0.86 „	1.54 „
Gold	+ 1.5 „	2.18 „

Practical experience shows that real danger of corrosion only begins after a voltage difference of more than 300 mV has been created. Therefore, connection contacts of Al–Zn, Al–Cr, Al–Cd offer practically no danger of corrosion. Iron bolts or screws galvanized or with a cadmium coating can, therefore, be used for bolting parts together such as aluminium bars.

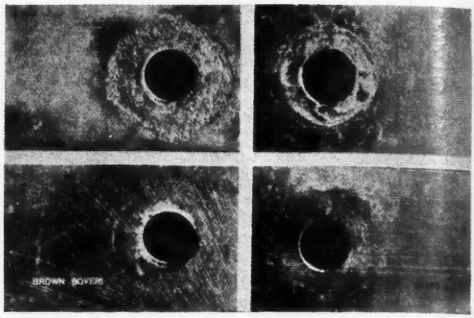


Fig. 2. Magnified view of the test pieces from *Fig.* 1.

However, certain deviations from the voltage scale can occur according to the atmosphere in which the pieces are placed, such as chemical vapours etc., as a result for example of the formation of salts. Thus, certain experiments show that iron may be on a lower potential scale than aluminium, in other words that iron and not aluminium corrodes.

Fig. 1, 2 and 3 show examples of corrosion tests. By means of systematic tests like these it was possible to lay down requirements as regards prevention of corrosion. Fig. 1 and 2 (magnified) show the result of the bolting of an Al bar to a Cu bar. The same method of bolting is used in both cases, but below, there is insulation between bolt and washer and above there is none. It is clearly seen what advantageous effect the insulation has, even under very severe conditions. In the bolting without insulation, it will be noted that there are points of attack also on the copper side; their cause is rust originating from the nut which has no Cd coating. Fig. 3 shows the effect of so-termed copper-plated intermediary layers, in the present case Cupal. After 55 days of immersion in salt vapour, the Al in direct contact with the Cu shows very marked signs of corrosion while the Al part in contact with the Cupal is unaffected.

As regards the working process, the possibilities of welding and soldering are most important. When exposed to air, aluminium gets covered immediately

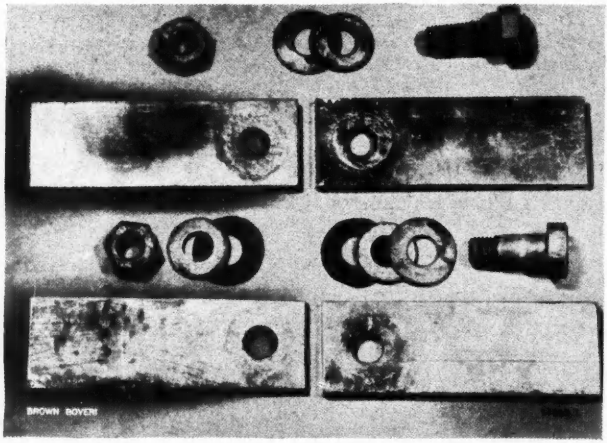


Fig. 1. Results of a corrosion test on a connection by bolts between aluminium and copper bars after 70 days' immersion in wet sea-water vapour. Right :—Copper bar. Left :—Aluminium bar. Upper connection without, lower connection with insulation of the steel bolt and washers.

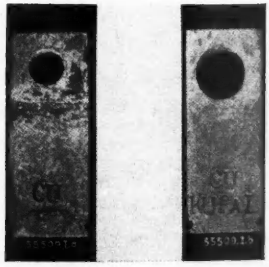


Fig. 3. Corrosion test in wet sea-water vapour on bolt connections with Cupal intermediate layer. Left :— Aluminium piece which has been in contact with copper. Right :—Aluminium part which has been in contact with Cupal.

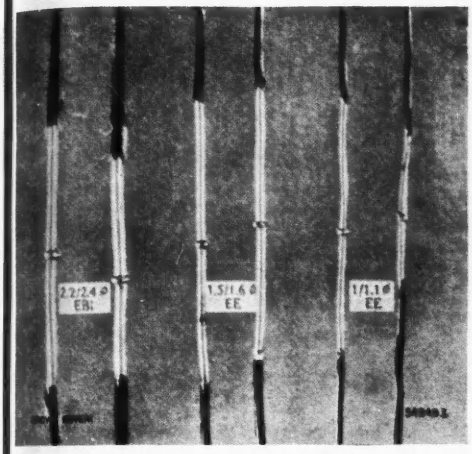


Fig. 4. Autogenous butt-welded Al wires, welded without using flux. Wires with enamel and enamel-cotton insulation, 1 to 2.2 mm. diameter of bare wire. The small ridges are the welds.

with a coating of oxide having a melting point of 2060° C, while it is 658° C in the case of pure aluminium. This oxide layer must therefore be removed chemically or mechanically before soldering or welding. Mechanical elimination is resorted to in the case of soft soldering; here the solder is rubbed on the preheated Al surface to remove the oxide layer; thus the surfaces of the parts to be connected are each subjected to a preliminary tinning. The soldering proper is effected by adding more solder: it is not necessary to use a cleaning flux in this process which has been known for a long time. In the other process, soldering or welding powder respectively, is used to remove the oxide layer; it is generally stirred into a paste with water and laid on to the seam. After soldering or welding, the seams have got to be carefully cleaned with water to get rid of the salts which then form, as these can cause corrosion. The solders or welding rods used have to be chosen to suit the material it is desired to join.

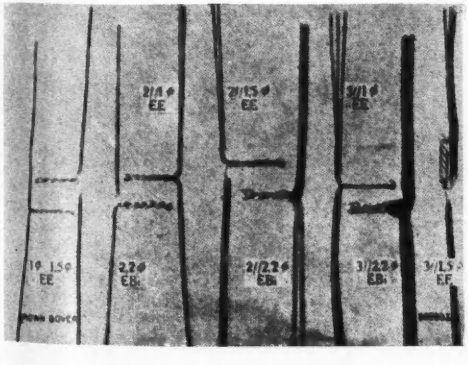


Fig. 5. Electrically welded Al wires of the same type as in Fig. 4, welded without using flux. Up to three wires in parallel.

Soldering by rubbing the solder on the preheated surfaces can only be used when thorough rubbing or scrubbing is possible, thus it is not suitable for small diameters or structural parts, further its application to windings is often impossible, as the latter are difficult of access. The use of soft soldering is also very restricted because, despite careful cleaning to remove remains of salt of the flux from the soldered parts, these solderings easily corrode. Even if a coating of varnish is resorted to, for example, the corrosion goes on; for parts which have narrow cracks between them, such as conductors laid parallel to one another, soft soldering is inadmissible in any case. Soft soldering is only reasonably safe for parts to be oil-immersed or placed in dry surroundings when the solder forms as smooth a surface as possible. Soft soldering allows iron, steel, copper and its alloys to be joined to aluminium.

Brazing is more advantageous than soft soldering. While the resistance to corrosion of a brazed point is inferior to that of a weld, its mechanical strength is considerably superior to that of soft soldering. An advantage of brazing as compared to welding is that thin parts and thick ones can be joined without special difficulty. Brazing is also to be recommended when the preheating requisite to good welding cannot be carried out. A disadvantage which is shared by soft soldering is the necessity of a flux which also demands effective cleaning of the seam, in this case as well.

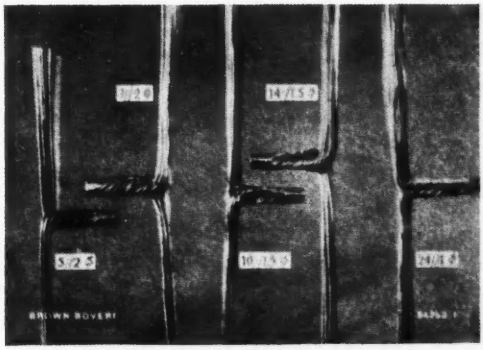


Fig. 6. Electrically welded bare Al wires of 1 to 2 mm. diameter, without using flux. Up to 24 wires in parallel.

Welding is the best process as regards resistance to corrosion and mechanical strength. It is therefore to be given preference when ever possible. Care must always be taken that the weld is properly carried out through and through so that no flux remains in the seam which could give rise to local corrosion. Suitable forms should be given to the parts in order to avoid this. Similar rules apply to the shapes to be given to Al parts to be welded as to those of steel, in order to obtain good welds. As the flux remains of the welding powder may also lead to corrosion in a damp atmosphere, the welding seams, after cooling, should be carefully cleaned with a brush and water.

In consequence of the possibility of corrosion, as a result of the presence of soldering and welding powder and considering that these materials, as well as the solder used in the preliminary tinning method without flux, contain substances which are getting very rare, autogenous electrical processes of connecting have been developed for making windings. Fig. 4–6 show examples of these methods.

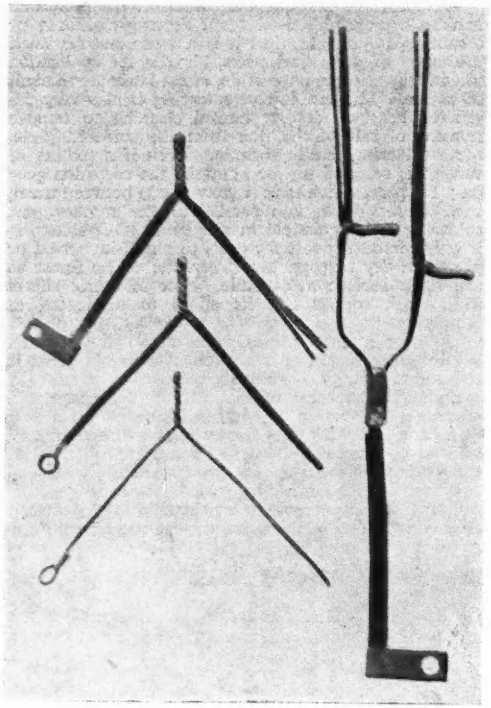


Fig. 7. **Copper-plated Al wires/Cupal/for winding connections.** At one end of the wire the copper is removed so that pure aluminium connections can be made. At the other end an ordinary soldering connection can be made. In the specimens shown on the left-hand side, the Cupal wire is always on the left and the aluminium wire connection on the right. The specimen shown on the right-hand side is composed as follows: upper part Al wire welded as *Fig.* 5; the middle is of Cupal welded; lowest connection at the thick part soldered to Cu cable in the usual way.

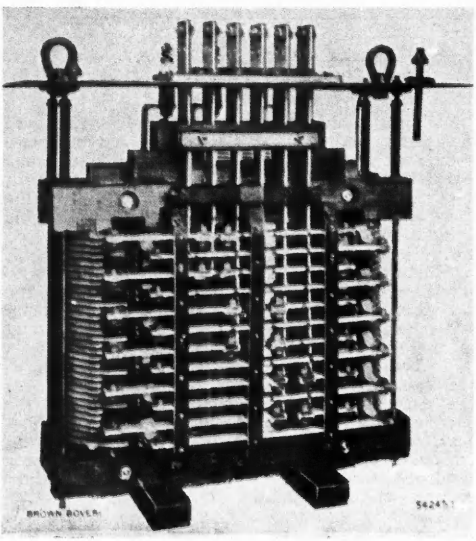


Fig. 8. Aluminium leads on the low-voltage side of a single-phase kiln transformer 180 kVA, 380/368V, 410/4100A, 50 cycles.

In the winding shops, copper-plated aluminium wires, so-termed Al-Cu or cupal wires, are used after the terminal plates (Fig. 7). At one end of the wire the copper is removed by pickling so that the aluminium below it allows of a pure Al-Al connection while, at the other end, an ordinary copper connection by soldering is carried out. Similar connections are used in transformer windings; connections by screws for small transformers are used, too. There is practically no danger through corrosive action, as the connections are oil-immersed. Fig. 8 and 9 show examples, which speak for themselves. Fig. 10 shows the so-called Schelling eye, a very advantageous solution of winding and cable connections, both for copper and aluminium, which eliminates any soldering.

As for the results of damage and the possibilities of repairing aluminium windings, it might be presumed that, e.g., an arc would have more serious results than in the case of copper, the melting points being 658° C and 1083° C of Al and Cu, respectively. However, the heat necessary for melting Al and its heat contents is so much higher than that of copper that it practically takes the same amount of heat to melt wires of equal resistance. Thus, the results of winding defects will be practically the same.

Machines with Al windings may be made for use on board ship, as the leads to the terminal plate are of copper and there are no parts subjected to corrosive influences on the winding itself. It is simply necessary to take the same measures as regards insulation as are adopted with copper windings to prevent direct attack of the aluminium of the winding.

The manufacture of the winding of squirrel-cage rotors of small motors by pressure casting has been standardized since some years for a power range up to about 15 kW. The manufacture of squirrel-cage motors, and of double slot motors of a bigger output with aluminium windings, however, was a more difficult problem. The difficult point is the communication of the necessary heat with the different sections of bar and ring and the small pitches encountered. However,

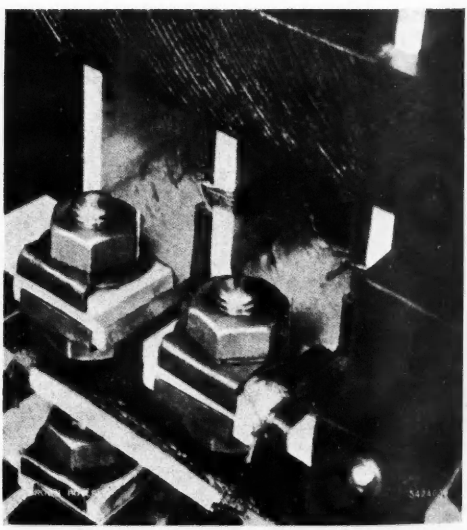


Fig. 9. Details of the leads of the transformer (*Fig.* 8). Autogenously welded angle pieces and screwed on cross connections.

Line and material	Cross section mm²	Section	View
Cable Cu and Al	up to 20		
Cable Cu and Al	over 20 up to 240		
Cable Cu and Al	over 240 up to 500		
Wire Cu	all sections		
Wire Al	all sections		

Fig. 10. Schelling-type eyes for connections without soldering.

these difficulties were solved and double-slot motors of 88 kW with brazed inner squirrel-cage connections and welded outer ones are now running.

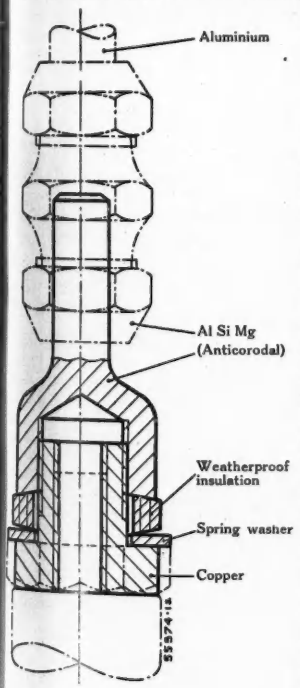


Fig. 11. Connection Al-Cu for outdoor plants.

For apparatus and switchgear plant, screws, brazing and welding are used, while for apparatus plated parts (Cu-plated Al structural sections) are often utilized and the soldering by preliminary tinning can also be resorted to, from time to time. Whenever possible, welded connections should be used, they are particularly useful in switch gear construction.

Because of differences in the heat expansion of Al, Cu and steel, it is necessary to place a spring washer (Belleville washer) under the nut of the bolted connections. These washers have to be strong enough to maintain a sufficient pressure both in a cold and warm state. The screws based on a tensile stressing of their section of 500 kg/cm² are to be chosen, so that there is a pressure of about 1 kg per ampere for current passing over only one connection surface and 1/2 kg per ampere when there are two or more connection surfaces. Steel screws and washers have to be cadmium-plated, parkerized or galvanised. The spring washers can only be parkerized or subjected to pickling because they are rendered brittle and weakened if treated with cadmium or galvanised.

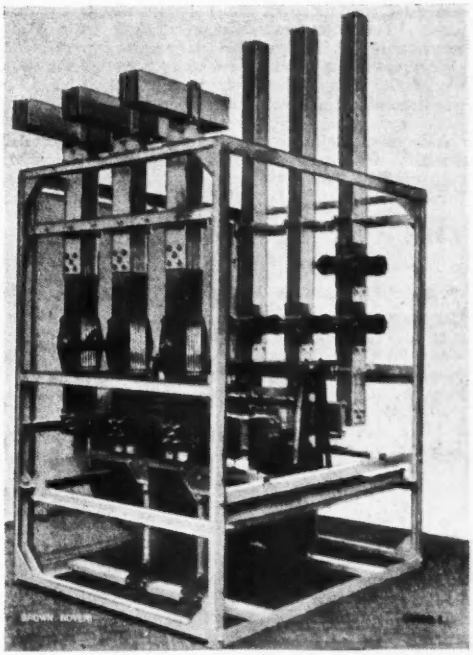


Fig. 12. Heavy-current disconnecting switch-frame.

It is important that the surfaces in contact before being screwed up should be well smoothed by filing and all oxide layers carefully cleaned away, and that they be given a thin vaseline coating immediately afterwards. The contact surfaces should not be treated with emery paper as this makes them rough. Al-Al and Al-Cu screwed connections in a dry atmosphere, or even in those which are damp for short periods only, need no other precautions. If the rooms are always damp or wet, the screws and washers for Al-Al

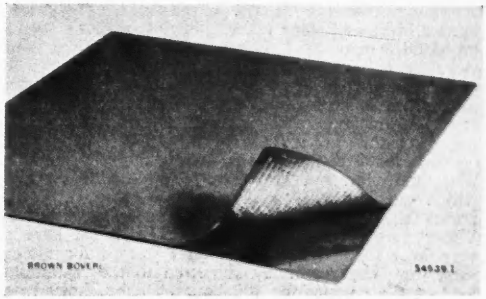


Fig. 13. Plated wood for apparatus casings.

and Al-Cu connections must be insulated from the bars. In extreme cases, when dealing with Al-Cu connections, it is advisable to use a copper-plated aluminium sheet as an intermediary layer. In outdoor plants the connector shown in Fig. 11 is used, or else intermediate layers of copper-plated aluminium. Fig. 12 shows a heavy-current switch frame. Fig. 13 shows plated wood, that is to say aluminium-plate wood which is used advantageously in apparatus construction.

If difficulties are encountered from time to time when using aluminium in the many fields it is so utilised, this should not lead to the general conclusion that it is unsuitable. Especially as regards corrosion, it is quite wrong to generalize on the basis of cases encountered in practice, which may be due to very exceptional circumstances. It should also not be forgotten that verdigris forms on copper and that iron rusts, which does not prevent these metals from being universally used.

THE USE OF PROPANE GAS FOR HEATING PURPOSES IN THE LABORATORY

By WILHELM OFFENBERG. (From *Stahl und Eisen*, Vol. 62, No. 45, November, 1942, pp. 948-949.)

LABORATORIES and small workshops situated in areas where no gas supply is available usually have to depend solely on electricity for heating purposes. The great disadvantage is that bunsens, blow lamps and blue burners, which are indispensable in most laboratory work, cannot be used.

The difficulty can be overcome by the use of propane gas.

An electric hot plate was converted to propane heating as follows :

A grey cast-iron plate measuring 800 mm. × 500 m.m. × 8 mm. was chosen. In order to obtain the best distribution of heat and to prevent cracking, the plate was ribbed (Fig. 1). Four burners, each with separate tap and pilot, were fitted. The outlets for gas-air mixture had a diameter of 2 mm. and were arranged along the burners at intervals of 10 mm. A gas meter measured consumption.

Using 247 litres of gas per hour the plate reached a surface temperature of 270°C. in 45 minutes from the cold. With the burners at their minimum consumption, i.e., 70 litres per hour, a constant surface temperature of 220° C. could be maintained.

By a suitable arrangement of burners it would be possible to heat only half of the plate, leaving the remainder for slow boiling down, etc.

It is important that the room in which the propane cylinders are stored should be well ventilated.

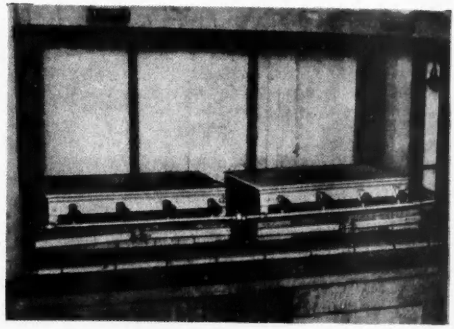


Fig. 1

NITRIDING PROCESS AND STEEL CORROSION

By GEORGE HIEBER. (From *Stahl und Eisen*, Vol. 62, No. 23, June, 1942, pp. 489-490).

IT has long been known that the treatment of ferrous metals by ammonia or some other nitrogen-yielding substance results in the formation of a film of nitride which renders the iron strongly resistant to corrosion. The great hardness of metal treated in this way and the large amount of wear and tear which it can withstand have given the treatment its popularity. In spite of many contradictory opinions on the effectiveness of nitriding against corrosion in general, it is universally agreed that this operation undoubtedly prevents attack by mild corrosives but does not render the metal proof against stronger agents. Differences of opinion have arisen with regard to the effect of sea water, salt solution, certain acids and some other strongly corroding agents on nitrided metals. This is because the solutions used were not of standard composition and strength. The experiments done by O. Hengstenberg have shown that nitrided steels, even after long standing in air, water, steam and steam-air mixtures, are not attacked by corrosion.

Nitrided steels not only withstand considerable wear and tear, but also have very smooth surfaces which enable them to slide without friction. This makes them invaluable for a number of purposes. Water pump spindles made of this material have a very long life. Spindles of water pumps for motor cars, were experimentally subjected to the maximum load of the engines for 100 hours. They showed no wear. Spindles made of chromium plated steel alloys, subjected to the same test were rendered useless.

Piston rods for heat engines can also be made of nitrided steel. Their resistance to corrosion is permanent.

Nitrided steel is often used as sealing material for super-heated steam fittings. The sealing plates, valve rings and slides show a resistance to steam erosion out of all proportion to that of stainless steel.

M. Knoerlein has demonstrated that nitrided steel can be subjected to a pressure of far more than 10 kg per sq. mm. as compared with the next best material—i.e. welded chromium—tungsten—cobalt alloy, which can stand 1/6 of that pressure only.

It has also been proved that nitrided steels are highly resistant to the corrosive effects of anti-knock fuel. Samples immersed for 6 months in petrol with an addition of lead-tetra-ethylene, remained unaltered, while un-nitrided steels showed marked corrosion. Nitrided steels can, therefore, safely be used for taps, cocks, plugs and other parts of tanks and of fuel piping. They can also be utilised with great advantage for delicate machine parts and measuring instruments which may have to be subjected to atmospheric moisture or to hand sweat.

Endeavours have recently been made to extend the nitriding treatment for the prevention of corrosion to steels other than those specially alloyed for the pur-

pose. D. Jachine tested a number of samples and found that an extraordinarily thin film of nitrate was sufficient to increase appreciably the corrosion resistance of such steels. A nitriding period of 30–10 minutes at 500° to 600° C. was found to be adequate. In order to save metal, use can now be made of these unalloyed nitrided steels for parts of welding burners which are particularly subjected to corrosive influences.

As an experiment some surgical needles were constructed of an unalloyed steel containing approximately 0.8 per cent. carbon. They were covered with a fine film of nitrate. After 24 hours' immersion in tap water, these needles showed no corrosion. Nickel plated needles tested at the same time showed stains of rust.

It is clear that many unalloyed and low-alloyed steels can be rendered highly resistant to corrosion, by nitriding of the surface, but it should not be assumed that every steel alloy, regardless of its composition, can be so improved. The corrosion resistance of a steel containing 18 per cent. chromium and 8 per cent. nickel, for example, is actually decreased by nitriding.

RECENT DEVELOPMENT OF TWO-STROKE ENGINES

By J. ZEMAN, VDI, Wien. (From *VDI*, Vol. 87, No. 1/2, January, 1943, pp. 7–14.

THIS article deals mainly with scavenging problems. The development of general design of two-stroke engines is the subject of another article which will be published as soon as available.

Scavenging.

The three chief problems of scavenging are: (1) to reduce the fuel loss through scavenging; (2) to determine the optimum cross section of the inlet and outlet ports and to fix their period of opening; (3) to determine the quantity of air for scavenging and hence to find the dimensions of the blower. Obviously these problems are closely connected.

The scavenging efficiency, the charging pressure and the crank angle at which this pressure is attained are important factors with regard to the mean effective pressure in the cylinders. The pressure and quantity of air delivered, on the other hand, determine the power absorbed by the blower, which together with mechanical losses must be deducted from the I.H.P. of the engine. There are, therefore, a number of design factors which finally will yield optimum results if they are suitable co-ordinated to one another. The multitude of these influencing factors make an experimental determination of the best dimension rather difficult; better results can be obtained from theoretical consideration of these, and actually this has been successfully done during the past years.

The ideal solution of the first problem mentioned above, would be the case when the scavenge is pushing burnt products into the exhaust pipe only, until the whole cylinder is just filled with scavenge. In this case, the scavenge remaining in the cylinder is equal to the fresh charge. Any additional scavenge forced into the cylinder represents a loss and in practice this is invariably the case. The scavenging efficiency is hence defined as the ratio of theoretically required quantity of scavenge to the quantity actually supplied.

Theoretical consideration of efficient scavenging has resulted in suitable design of flow conditions as shown in Figs. 1, 2, 3 and 4. The first two represent uni-flow scavenging where the inlet and outlet ports are at the opposite ends of the cylinder respectively. The last two Figures show loop-scavenging with inlet and outlet ports placed at the same end of the cylinder. A modification of loop scavenging would be to arrange the ports in such a manner that the flow takes place in a straight horizontal direction. This might be practicable only in engines of a very short stroke.

The flow conditions with uni-flow scavenging are easy to determine and hence they give good results. Due to its simplicity little development marks this system and Figs. 5–14 show a variety of engine designs all employing uni-flow scavenging. The earliest type (Fig. 5) used in U-boat engines during the last war, has an inlet valve at the top of the cylinder while the outlet takes place through piston controlled ports. Almost at the same time the opposed piston type engines were brought to the market with the result that valves disappeared from two-stroke engines for a long time. Only when in four-stroke engines the valve operation was perfected to a high degree, were they used again in two-stroke engines (Fig. 13), but the inlet was still taking place through ports. In very recently designed engines, valves are employed for both inlet and outlet.

With the appearance of high speed engines, difficulties were encountered with both the valve controlled and the opposed piston type of engines. In the first case the valves could not be opened quick enough due to inertia forces, and a solution was sought in increasing the cross section of valves or to use slide valves. With the opposed piston engines, the inertia forces in the connecting rods become excessive. This difficulty was overcome by arranging the pistons parallel (Fig. 11), or by using gear transmission as shown in Fig. 8. Still another solution is to reduce the weight and stroke of one of the pistons (Fig. 12), which really leads to slide valve controlled engines. Although extensive investigations are covering the fields of slide valve controlled two-stroke engines and there are a number of engines in use, they have not yet reached the stage of mass-production nor could a survey be made of their operation.

In those countries where economical considerations are of prominent importance, e.g., Germany, two-stroke engine development followed the loop scavenging system. The arrangement of both inlet and outlet ports at the same end of the cylinder makes it possible to utilize the motion of one piston to control all ports. This method involved investigations in two directions,

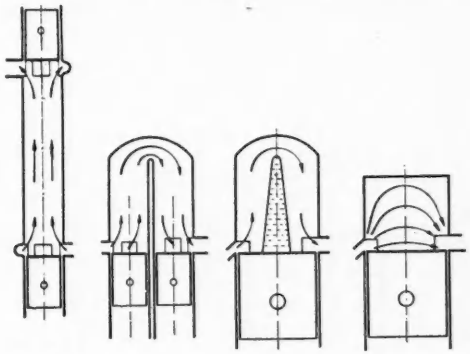


Fig. 1 *Fig.* 2 *Fig.* 3 *Fig.* 4

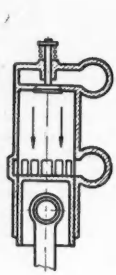


Fig. 5

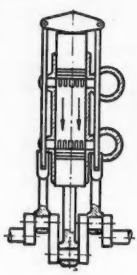


Fig. 6

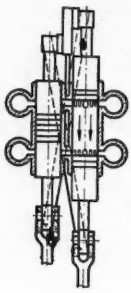


Fig. 7

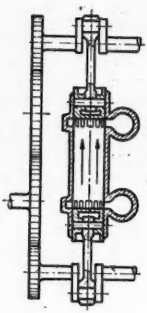


Fig. 8

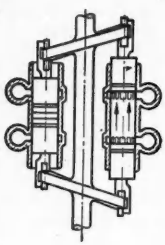


Fig. 9

Fig. 5. MAN (old) Bolinder-Munktell wood-gas-engine

Fig. 6. Junkers Doxford

Fig. 7. English Electric Fullagar

Fig. 8. Junkers, Co. Lillaise d. Mot., Fairbanks-Morse

Fig. 9. Research Institute, Boston

Fig. 10. Dankworth, Sulzer, Hill, Junkers-Allach

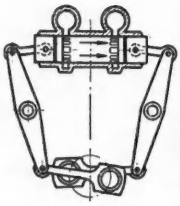


Fig. 10

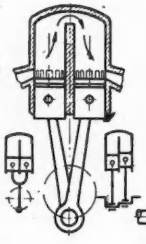


Fig. 11

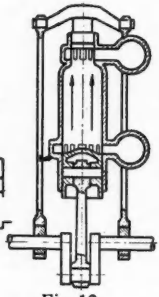


Fig. 12

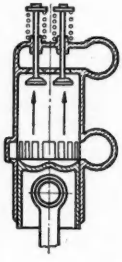


Fig. 13

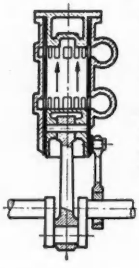


Fig. 14

Fig. 11. Puch, Triumph, Auto-Union, Rekord

Fig. 12. Burmeister & Wain, Burn

Fig. 13. Krupp, Bethlehem, Burmeister & Wain, NACA, Petters, General Motors, Alfa-Romeo

Fig. 14. Ricardo.

(*a*) to establish a method by which the scavenging efficiency can be ascertained, and (*b*) to develop a construction which will give a high scavenging efficiency.

To (*a*). The methods developed permit either a study of flow conditions in the cylinder or a quantitative measurement of scavenging efficiency in scale model or actual engines. In scale model engines the accuracy of measurements is high but it is difficult to reproduce actual engine conditions. In actual engines, on the other hand, gas samples provide a means of estimating the scavenging efficiency when, of course, the accuracy depends on how far the gas sample approaches the true mean gas composition in the engine. Engine output, too, can be used for obtaining comparative figures of scavenging efficiency. A study of the flow conditions cannot give actual efficiency figures, of course, but as it has a certain relation to the efficiency it provides an indirect comparative method.

To (*b*). Figs. 15–24 show a variety of loop scavenge designs developed which operate as follows :

(1). Figs. 15 and 16. The scavenge is guided by deflector plates on the piston crown.

(2). Figs. 16 and 17. The scavenge is guided by inclined ports (deflection ports).

(3). Fig. 19. Krupp method consisting of sucking out the boundary layer between scavenge and cylinder wall.

(4). Fig. 20. Fottinger-Wille method. The boundary layer is blown away at the point of inflection.

(5). Fig. 21. Reverse loop scavenge with outlet ports above the inlet. (System MAN.)

(6). Figs. 22 and 23. As (5) but with inlet and outlet ports side-by-side.

The oldest method of using deflector pistons gave satisfactory results if the plate could be designed high enough. In high compression ratio engines, particularly in C.I. engines, however, this method could not be used. It was, therefore, necessary to design flat piston crowns and the scavenge was governed by inclined ports (deflector ports). In this case it was essential to use a blower to maintain sufficiently high

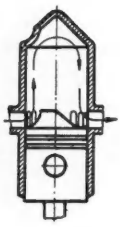


Fig. 15

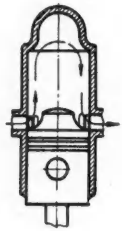


Fig. 16

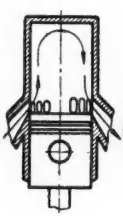


Fig. 17

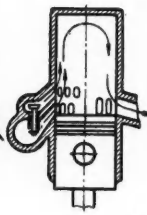


Fig. 18

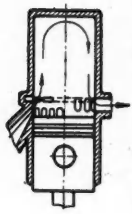


Fig. 19

Fig. 15. Fichtell Sachs, Bolinder-Munktell, Lanz, Ilo, Hatz

Fig. 16. Hanseatic Motor Co., Scott, Gardner, Hille

Fig. 17. Jung, Bolinder, Fiat, Worthington, Nordberg, Motosacoche

Fig. 18. Sulzer, Tosi, Fiat, Bolinder

Fig. 19. Krupp.

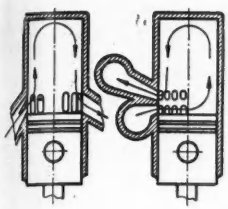


Fig. 20

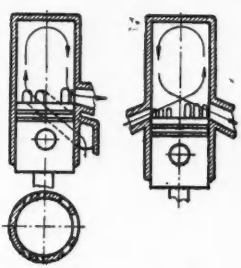


Fig. 21 *Figs.* 22 & 23

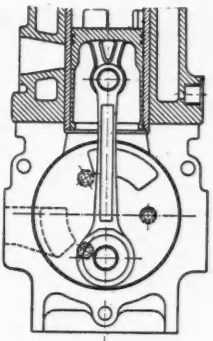


Fig. 24

Fig. 20. Fottinger-Wille

Fig. 21. MAN, Motosacoche

Figs. 22 *and* 23. Deutz, Atlas, Auto-Union, Nohab, Fairbanks-Morse, Modaag, Polar

Fig. 24. AEG-Hesselman, Stork - Hesselman

pressure in the cylinder. Small ports are arranged above the scavenge ports through which additional air is forced in the cylinder. The ports were provided with automatic or valve control. Engines with short strokes, particularly with crank case compression, and therefore small scavenge flow, require no auxiliary charging devices.

Unsatisfactory scavenging with deflector ports is due to scavenge parting from the cylinder wall above the ports and trying to take the shortest route to the outlet port. This parting is caused by a turbulent air pocket which increases as scavenging proceeds and which pushes the air stream away from the wall. According to Krupp's method, this turbulent air layer is sucked away through small auxiliary ports located above the inlet port and connected to the exhaust pipe. The improvement with this solution is so great that it makes supercharging superfluous in many cases. (Fig. 11).

The problem is solved in a different manner in the Fottinger-Wille system. Here the turbulent layer is blown away from the point of scavenge inflection by means of specially constructed nozzles. (Fig. 20).

A very popular design is shown in Fig. 22, where the ports are so arranged that the scavenge is blown to the wall opposite to the outlet ports where it is reversed to the outlet ports.

In small engines the ports cannot be arranged in two rows, one above the other, and in this case it is necessary to arrange a swirl scavenge. The incoming air is directed against the wall opposite the outlet port (Figs. 22 and 23). Finally there are also some mixed methods of scavenging as for instance the type shown in Fig. 24.

The desire to increase the power of two and four-stroke engines has resulted in supercharged engines in which the pressure in the cylinder is higher than atmospheric just after closing of the ports. This involves in every case a pre-compressing of the air charge, usually by a special pump. The magnitude and efficiency of supercharging depends upon the efficiency of the pump unit and its driving mechanism.

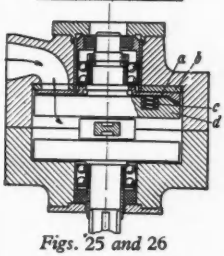
Pressure equalization through the outlet ports can be prevented either by early closing of outlet ports relative to the inlet ports or by throttling of the exhaust. Both methods are utilized in two-stroke engines. Early closing of the outlet ports results in unsymmetrical timing diagrams. As a rule only one row of ports is unsymmetrically controlled, usually the outlet ports, as in this case charging is completed earlier than with unsymmetrical inlet port control.

From the constructional point of view this is achieved in the following manners.—

(1). Unsymmetrical inlet port operation: an automatic or a controlled opening and closing mechanism is preconnected to the ports. With valve operated engines, suitable setting of valve closing.

(2). Unsymmetrical outlet port operation: an opening and closing mechanism as before; opposed piston, auxiliary piston and slide valve engines.

The uniflow scavenging system contributes also in this respect to a simpler solution.



Figs. 25 *and* 26

The throttling method is less frequently employed, mainly because it is not so efficient as the solution previously mentioned. On the other hand it is very simple and it renders two-stroke engines insensitive to unfavourable exhaust gas condition. Exhaust gas turbine represents another variety of the throttling method and is rapidly gaining ground.

Scavenging Pumps.

(1). Reciprocating pump. The original scavenging pumps had the following features. It was a double acting valve (seldom slide valve) controlled pump with a drive from the cross head or from a separate crank. Much more popular is, however, the crank case compression type of engine, Figs. 25 and 26. Its main advantage is great simplicity. The air inlet of the crank case of large and medium engines, is fitted with a flap or an automatic valve, while in small and high speed engines, slots in the cylinder wall and in the piston skirt are provided for this purpose. In later designs, rotary valves are frequently employed as otherwise the length of the effective stroke would be reduced. Efficient operation of crank case pumping requires that the part of pumping period which coincides with the scavenging of the associated cylinder should take place at decreasing cylinder pressure. To this end the gas column oscillation in the exhaust pipe must be "tuned" accordingly. The solution is relatively simple in constant speed engines, but it becomes complicated in motor car engines where the constant speed variation influences the oscillation of the gas column. Improvements in this line have resulted in such an increase of the pumping efficiency in engines with symmetrical timing diagrams, that a further increase would be undesirable from the point of view of scavenging efficiency. Still higher pumping efficiency is aimed at, however, in Otto,—C.I. and injection type engines with unsymmetrical timing diagrams.

It is of interest that a compromise solution, by retaining the crank case compression but increasing the pumping efficiency by an auxiliary pump or by

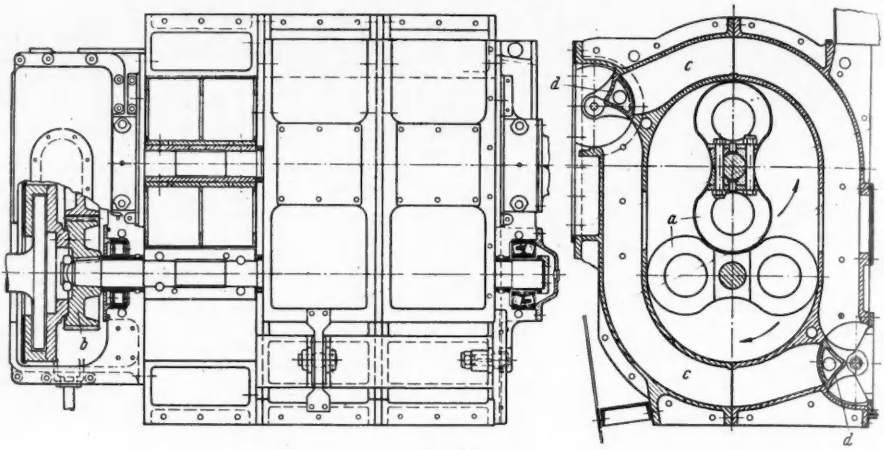


Fig. 27

plungers driven by the main shaft has not proved practicable. Correspondingly further development can only be hoped from still further improvement of the conditions of gas column oscillation. In Germany, the " Kadenacy " method of scavenging is already being employed in some cases. This system uses only the exhaust gas oscillation for scavenging. Experiments carried out by Daimler-Benz have shown that in this way very good scavenging efficiency can be obtained within a limited speed range. A more practical solution for vehicle engines seems, therefore, to be indicated by the combination of crank case pumping and the " Kadenacy " method.

Vane Type Blowers.

Two or multi-teethed roots blowers find also frequent applications in two-stroke engines. Accuracy of manufacture and design have increased their maximum speed above that of the engine so that their dimensions can be kept low. Fig. 27. To provide a vibration-free drive from the main shaft a vibration damper is usually incorporated in the gear transmission unit. Further improvement regarding vibration and noise can be obtained by a staggered arrangement of the teeth (Fig. 27), or in smaller units, by helical lobes (Fig. 28). Other types of vane blowers are rarely used probably because of the difficulties encountered at high speeds.

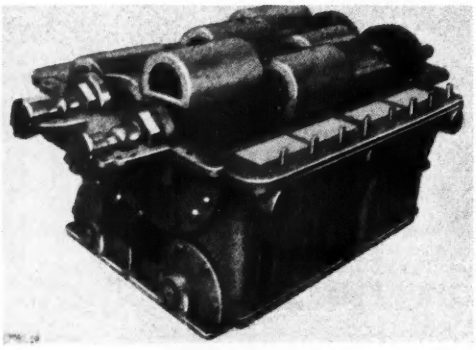


Fig. 28

Centrifugal Blowers.

Centrifugal blowers are rapidly gaining ground in spite of the initial belief that their application will be hampered by speed variations of the engine which will alter the delivery pressure and volume. Hydrodynamic flow analysis brought about great improvements and further developments included a design of vibration-free gear transmission ; aero engine supercharging in particular had a great influence on this development. At the present, centrifugal blowers are driven by the main engine, but in the future this will probably be replaced by exhaust gas turbines as already indicated.

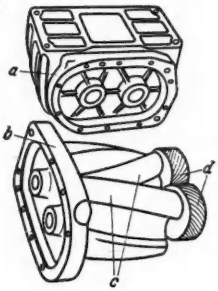


Fig. 29

In ship engines, reversibility is also an important feature, and although uni-directional drive of the blowers gives best results, great improvements have been also achieved with reversible blowers.

THERMAL EXPANSION OF LAMINATED PLASTICS

By R. VIEWEG and W. SCHNEIDER. (From *Kunststoffe*, Vol. 32, No. 10, October, 1942, pp. 295-297).

EXPERIMENTS carried out by the authors, show that the coefficient of thermal expansion of laminated phenolic plastics is different perpendicular to the laminations from that in their plane, although substantially the same in two mutually perpendicular directions in the

plane. Tests were made on pieces 120×15×10 mm., except for those cut perpendicular to the laminations, which were only 60×15×10 mm. The heating rate was 20° per hour up to 120° C. for the fabric base and 100° C. for the paper base material. The test pieces were then maintained at this temperature for 19 hours and the total shrinkage in mm. per m. (mils per inch) recorded. The table shows the results, β_x, S_x referring to the plane of the laminations and β_z, S_z to the perpendicular direction.

MATERIAL	Average value of coefficient of linear expansion $\beta_x \times 10^6$ $\beta_z \times 10^6$	Contraction Temperature °C.	Total contraction in mm/m. S	S
Fine fabric base	45 70	120	4.0	7.8
Coarse fabric base	50 67	120	3.3	5.3
Paper base ..	25 140	100	1.0	6.3

ENGINE-COOLING PROBLEMS ARISING IN MOTOR-CAR DESIGN

By Dr. Ing. B. Eckert, VDI/ATG. (From *ATZ*, Vol. 45, No. 9, May, 1942 (Part I), pp. 233-238.)

Hitherto, the power required for cooling purposes alone has not been separately considered, although it may amount to anything up to 20% of the engine power. In the usual power balance sheets of automobiles, therefore, the power required for cooling is not separately represented. Its greater part, with passenger cars, is due to air resistance.

The total power required for the cooling of the engine can be subdivided into :—

(*a*) The power necessary to overcome the air resistance of the vehicle.
(*b*) Power for the fan.
(*c*) Power absorbed in carrying the extra weight of the cooler.
(*d*) Power for the coolant pump.

The following considerations are equally applicable to both air-cooled and liquid-cooled engines.

Symbols of the more frequently used Terms.

A (kg.) = Lift.
b (m.) = Radial dimension of the fan blade.
c_a (—) = Lift coefficient.
c_m (m./sec.) = Mean velocity of flow through blower.
c_p (kcal/kg. °C.) = Specific heat of air.
c_w (—) = Drag coefficient of blade section.
c_{wki} (—) = Drag coefficient at station i of air duct.
c_{wko} (—) = Drag coefficient of cooler.
F_K (m²) = Frontal area of cooler.
g (m./sec.²) = Acceleration due to gravity.
h, H (m.) = Pressure head.
l (m.) = Blade chord.
l_K (m.) = Depth of cooler.
N (h.p.) = Required power.
Index G Blower.
K Cooler.
P Coolant pump.
Δp (kg./m.²) = Pressure gradient.
Δp_{stat} (kg./m.²) = Static pressure increase in blower.
Δp_{tot} (kg./m.²) = Total pressure increase in blower.
$q_{(kcal/hdm^2\,°C.)}$ = Power absorbed in cooling, per degree temperature gradient.
$Q_{k\,(60°C)}$ (kcal/hdm²) = Cooling power at 60° temperature gradient.
t (m.) = Pitch of aerofoil rows.
t (°C.) = Temperature.
Index L_E Air inlet.
L_A Air outlet.
W_E Water inlet.
W_A Water outlet.
$\bar{t}_W$ (°C.) = $\frac{t_{W_A} + t_{W_E}}{2}$ Mean coolant temperature
Δt (°C.) = $\bar{t}_W - t_{L_E}$ = Gradient between mean coolant temperature and air inlet temperature.
Δt_L (°C.) = $t_{L_E} - t_{L_A}$ = Increase in air temperature between inlet and outlet.
T (°C.) = Absolute temperature.
k (—) = Coefficient of thermal conductivity.
v_a (m/sec.) = Air velocity at outlet.
v_F (m/sec.) = Speed of vehicle.
v_K (m/sec.) = Velocity of airflow through cooler.
ν (m³/kg.) = Specific volume.
V (m³/sec.) = Rate of flow.
W (kcal/h) = Amount of heat to be dissipated.
W ∞ (m/sec.) = Mean relative velocity of airflow.
z (—) = Number of blades.
ϵ (—) = $\frac{c_W}{c_a}$ = Glide angle.
γ (kg./m.³) = Specific weight (of cooling agent).
ζ (—) = Coefficient of utilization of stagnation pressure.
η (—) = Efficiency.
Index A Plant.
G Blower.
L Airduct.
Mech Mechanical.
P Pump.
R Rotor.
φ (—) = Rate of delivery.
Index ∞ = Related to inviscid flow.
ρ (kgsec.²/m.⁴) = Density of air.

(A) Relations between Power absorbed in Cooling and that necessary to overcome the Air Resistance of the Vehicle.

The work which must be done to cool the engine, expressed as " internal drag " amounts to about 10% of the total air resistance with conventional cars, and up to 25% with streamlined cars. With aerodynamical refinements of the body, especial care is necessary, therefore, in designing of the cooling system.

I. Entry of Cooling Air.

Fig. 1 shows the pressure distribution over a car of orthodox shape where the cooler (radiator) is usually in the front. There is positive pressure where the air enters the cooler, and negative pressure where it leaves through the gills at both sides of the bonnet. (Shown in plan view.) The following considerations will be illustrated by means of an example.

To cool a 80-h.p. engine, about $Q = 60 \times 10^3$ kcal/h. have to be carried away by the coolant. Assuming $t_{W_E} = 90°$, $t_{W_A} = 85°$ C., thus $\bar{t}_W = 87.5°$ C., $t_{L_E} = 30°$ C., and thus $\Delta t = \bar{t}_W - t_{L_E} = 57.5°$ C. From the diagram

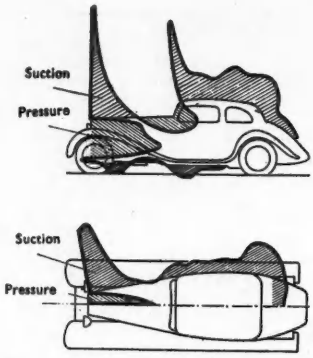


Fig. 1

given in Fig. 2 (Behr, "Automobiltechnisches Handbuch," 14th Ed., Berlin, M. Krayn, 1941) it follows that for minimum work expended in cooling the engine v_k must be small and the cooler as flat as possible. Choosing $v_k = 10$ m./sec. and the depth of the cooler $l_k = 55$ mm., we obtain from diagram

$$Q_k = 1400 \text{ kcal/hdm}^2$$

for $\Delta t = 60°$ C., on which value the diagram is based. For the present example $\Delta t = 57.5°$ C., and

$$9 \Delta t = \frac{1400}{60} \cdot 57.5 = 1342 \text{ kcal/hdm.}^2$$

The required frontal area

$$F_k = \frac{Q}{9 \Delta t} = \frac{60{,}000}{1342} = 44.5 \text{ dm.}^2$$

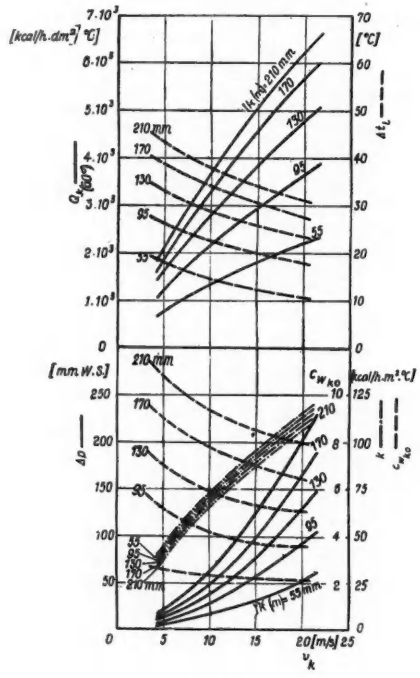


Fig. 2

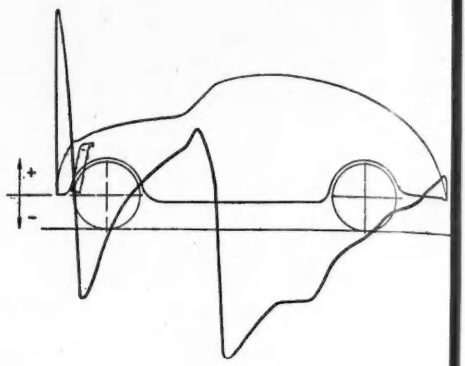


Fig. 3

For square design of the cooler the dimensions of the frontal area becomes

670 mm. × 670 mm.

The drag coefficient of this cooler (from Fig. 2) $C_{W_{ko}} = 2.3$.

Thus, the required cooling power

$$N_K = \frac{V \Delta p}{75} = \frac{F_K \frac{\rho}{2} v_K^3 c_{W_{Ko}}}{75} = 0.85 \text{ H.P*}$$

As Fig. 1 shows, the air exit through gills lies in the zone of negative pressure, i.e., of greater speed than that of the vehicle. The disturbance of the general air stream, and the corresponding drag increase by air issuing through the gills, is greater than the gain by efflux propulsion. With the aerodynamic improvement of the shape of the vehicle, the available frontal area of the cooler becomes smaller. This is obvious from Fig. 3, showing a better streamline body than that of Fig. 1. This fact becomes still more distinct with the fully streamline body shown in Fig. 4. In both Fig. 3 and Fig. 4 the pressure distribution over the vehicle is shown. Fig. 4 shows symmetrical

* Throughout the article metric units have been used, and 1 H.P. = 75 kgm./sec. = 0.9863 Brit. H.P.—The Editor.

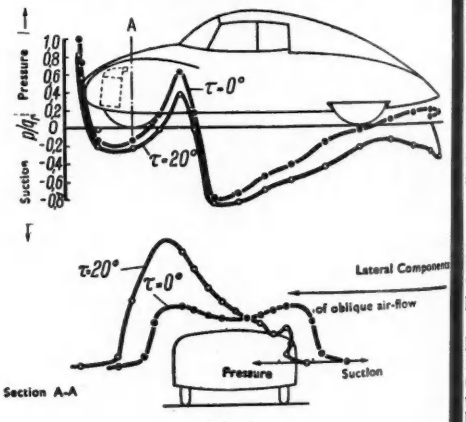


Fig. 4

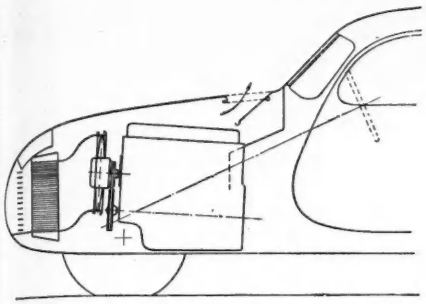


Fig. 5

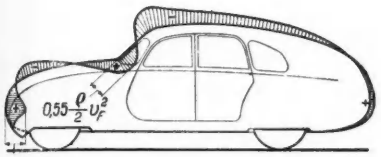


Fig. 6

flow $\tau = 0°$ and a flow at $\tau = 20°$, oblique to the car. Again we calculate the cooling power for the two cars in Figs. 3 and 4 by using the previous example. Assuming that there is room in the car of Fig. 3 for a square cooler of 450 mm. by 450 mm., then with the assumptions of the previous example at $\Delta t = 60°$ C.,

$$Q_k = 3100 \text{ kcal/hdm.}^2,$$

and by using the diagram in Fig. 2, at $v_K = 15$ m./sec. and a cooler depth $l_K = 95$ mm., the required power

$$N_K = 2.14 \text{ H.P.},$$

i.e., 2.5 times that required in the previous example.

The cooler dimensions for the car shown in Fig. 4 with a box-shaped body structure will have to be reduced still further, say, to 315 mm. × 315 mm. Then, for $v_K = 20$ m./sec., and the depth of the cooler $l_K = 210$ mm., at $\Delta t = 60°$ C.,

$$Q_K = 6150 \text{ kcal/hdm.}^2$$

and $N_K = 5.35$ H.P.

For the same engine power the respective required cooling powers for the three shapes are in the ratio of

$$1 : 2.5 : 6.3.$$

Assuming present-day ducts under the bonnet the power for the blowers are in the ratio of

$$3.40 : 8.56 : 21.40.$$

This shows that with improved aerodynamical shapes of the vehicle the cooling and power problems require careful consideration.

II. Outlet of Cooling Air.

The position of the cooling air outlet is more important than its design. If the exit is just below the wind screen (*Fig.* 5), some advantages can be gained within a certain speed range, as has been found from extensive experiments. The energy of the cooling air at the exit is added to the airflow in this

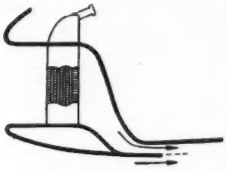


Fig. 7

stagnation corner so that there is a smaller pressure rise whereby a possible breakaway is avoided. The energy thus freed is of about the order of the power absorbed in forcing the air through the radiator. The pressure distribution over the meridional section of the Kamm(K)-car (*Fig.* 6) indicates that at the cooling-air exit for a closed bonnet, the pressure amounts to:

$0.55 \frac{\rho}{2} v_F^2$, i.e., of the total stagnation pressure a part,

$$0.45 \frac{\rho}{2} v_F^2$$

is available for assisting the cooling air on its way. The additional energy required must be supplied by the axial flow blower, to some extent even when the outlet is open. This led to consider other locations for the cooling air exit. It appears that the position of the exit on the underside of the car offers some promise. Pressure distributions have shown that for this location there is nearly undisturbed air pressure, in some cases even slight suction. Wind tunnel measurements proved that with a layout according to Fig. 7 a minimum cooling power can be achieved without increase of the drag coefficient of the vehicle. The dimensioning of the cooling air duct should be such that the energy $\frac{\rho}{2} v_a^2$ of the hot air exit to be supplied by the blower is a minimum. Best results can be expected with a velocity ratio of $\frac{v_a}{v_F} \simeq 0.3$.

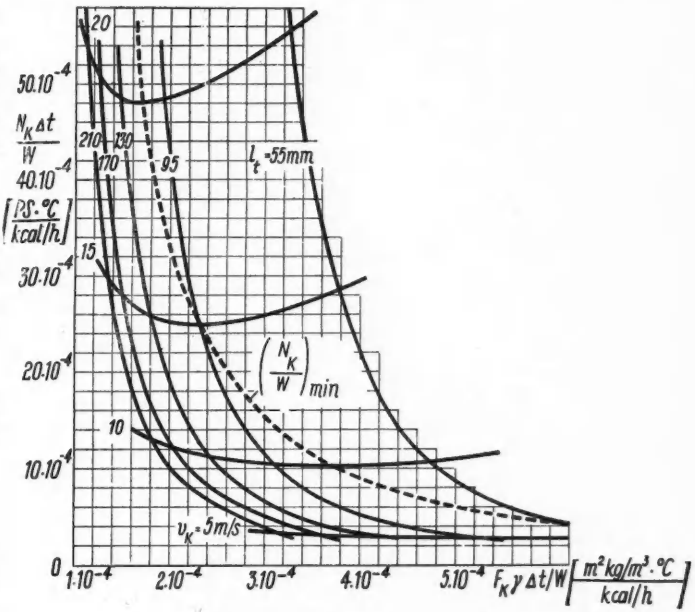


Fig. 8

III. The Influence of the Cooler Dimensions on the Power required.

The foregoing investigation has brought out the desirability of a large frontal area of the cooler, and herewith a low velocity of airflow through it. The radiator, therefore, will have to be built with as large a frontal area as the aerodynamic shape of the bonnet allows. Further, the exit velocity from the bonnet must be as low as possible.

If we assume that the air enters and leaves at the same speed, and the exit is located so as to lead into undisturbed air, the cooling power, without exploiting the stagnation pressure due to the velocity of the vehicle, is

$$N_K = \frac{\rho}{2} v_K^2 (Cw_{KO} + 1) v_K F_K \frac{\eta_A \cdot 75}{1} \text{ H.P.}$$

The amount of heat to be dissipated is

$$W = 3600 v_K F_K c_P \gamma \Delta t_L \quad \text{kcal/h.}$$

Assuming $c_P = 0.241$ kcal/kg.°C. and $\eta_A = 1$, one gets the expression

$$\frac{N_K \Delta t}{w} = \frac{60}{2 \times 3600 \times 75 \times g \times Cp} \cdot \frac{v_K^2}{\Delta t_L} (Cw_{KO} + 1) =$$

$$= 0.47 \times 10^{-4} \frac{v_K^2}{\Delta t_L} (Cw_{KO} + 1) \quad \frac{\text{HP h °C}}{\text{k cal.}}$$

By applying this equation to the present set of coolers (Fig. 2), a diagram is obtained which is given in Fig. 8. It shows that that ratio $\frac{N_K \Delta t}{w}$ becomes favourable with increasing l_K and decreasing v_K. Fig. 8 shows further that for v_K = constant there is a minimum value for $\frac{N_K \Delta t}{w}$. Connecting all these minimum points, a curve is obtained, (dotted)

$$\left(\frac{N_K \Delta t}{w}\right) \min = f\left(\frac{F_K \Delta t \gamma}{w}\right),$$

which gives the optimum value of the ratio $\frac{N_K \Delta t}{w}$ for various values of v_K. For each v_K a minimum cooling power is obtainable at a given value of l_K or frontal area.

The design of the ducted system and of the blower from the point of view of saving losses, further the influence of the radiator weight and the power required for the coolant pump will be dealt with in the next issue of the *Engineers' Digest*.—The Editor.

WELDING SETS OF INSTANTANEOUS-REACTION TYPE FOR D.C. ARC WELDING

By H. KOCHER. (From *Brown-Boveri Review*, Vol.29, No. 4, April, 1942, pp. 100-105.)

BESIDES the static characteristic which represents the current-voltage curve of the machine under steady conditions, there is also a dynamic characteristic which gives the variation of the voltage when a sudden load or current fluctuation occurs. It expresses by how much the field in the armature of the generator, that is its e.m.f., varies during a compensating process inherent to a given variation in current. The dynamic characteristic of a machine can be qualified as satisfactory when a short-circuit current surge does not exceed a certain magnitude and when, after the stable short-circuit current is interrupted, the recovery voltage—i.e. the voltage which appears across the terminals at the moment the current is suppressed—is not below a given magnitude. This second condition above all is the deciding one. Tests and practice show that with ordinary electrodes, ignition is perfectly satisfactory when the recovery voltage attains about 30 V or more immediately after the ignition short circuit, that is after the electrodes are raised.

In most of the well-known welding generators, the dynamic characteristic is produced by a counter field acting in counter sense to the main field and generated by a main counter current winding which is magnetically independent of the other windings. In the new welding generator the same result is achieved by a novel arrangement (Fig. 1). For the sake of simplicity, the illustration only shows one main and one interpole. The dynamic counterfield is here generated by the interpole winding c, which is available in any case, with the aid of magnetic auxiliary circuits m, built or as prolongations on one side of the main-pole shoes. The result of this is that the interpole winding is loaded with a constant current, that is statically; there is, besides the necessary commutating field, only a stray field s. Another possible flux, such as one passing through the magnetic circuit g, will not be set up because the reluctance which it has to overcome is, obviously, much greater than that of circuit s. Therefore, the e.m.f. of the machine will not be otherwise influenced by the new design. The flux distribution is immediately modified, however, when the current passing through the windings of the interpoles is subjected to a sudden variation. Now, the stray flux s can no longer follow the quick changes because field coils a and b function as damping windings. This damping effect acts like an increase in the reluctance of the cores of the main poles, a reluctance which is the greater the more rapid the variations of current. As a result of this a counter field generated by the interpoles is forced to pass through the magnetic circuit g which presents no damping resistance; this field is practically in phase with the main current. Thus, the machine is able to vary its e.m.f. suddenly and thus to adjust itself to rapid fluctuations of the welding current.

In machines of the ordinary design, the counter field which generates the dynamic characteristic also acts under static current loading so that it is necessary to overcome the static counterfield by a corresponding

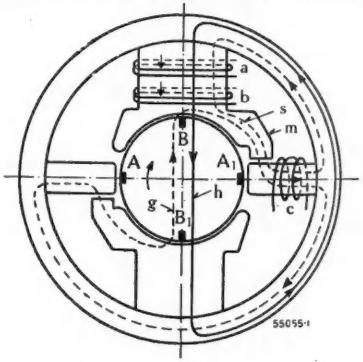
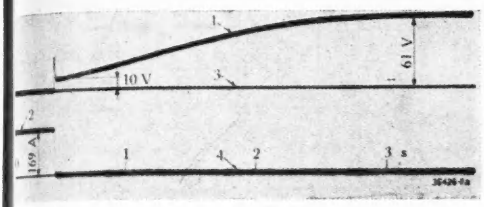
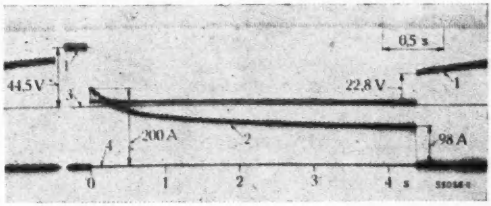


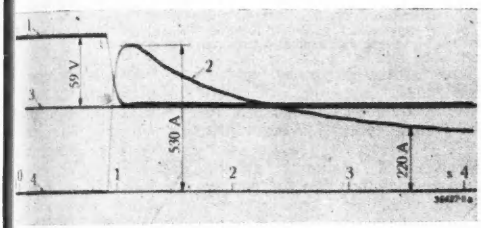
Fig. 1. Magnetic system of the new welding generator.
a, b. Field coils, *c* Interpole coil, *m* Magnetic auxiliary circuit, *A, A1* Main brushes, *B, B1*, Auxiliary brushes.



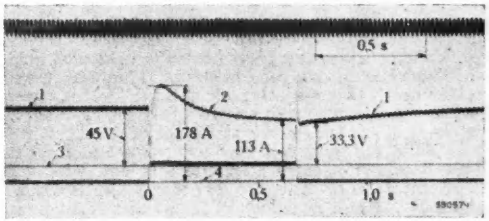
(a) Ordinary shunt generator.



(c) Instantaneous reaction generator with main current counter-compound winding.



(b) Ordinary shunt generator.



(d) Generator of latest design (Type QGS 60).

Fig. 2. Switching in and switching out processes, from no-load to short circuit and vice-versa.

increase in the excitation of the field for every loading point. Therefore, limits are set to the choice of the number of counter ampere turns in these machines for reasons of economy which obviously affects the quality of the dynamo as welding generator. Attempts are frequently made to overcome these difficulties by carrying out changes in the winding and terminal connections within the range of current regulation, but this solution is troublesome to put into effect. In the new generator, the counter field only comes into action for the duration of current changes, and plays no part during static loading. Therefore the designer is free to choose the number of counter field ampere turns so that they satisfy the dynamic requirements of the whole current range; it is unnecessary to enlarge the field coils.

Apart from what has been described, the new welding generators present the following innovations. In most welding machines, a separate main-current counter-compound winding is used in order to allow of attaining the lowest possible welding current. This is generally impossible with purely shunt excitation. The excitation of this counter-current winding increases proportionately to the welding current to attain a maximum when the welding current reaches its peak. This limits the range of the welding current or else, for a given maximum current, the expense for excitation becomes relatively big. In the new generator a field-weakening winding is used supplied from auxiliary brushes and acting indirectly. This winding is so connected that its excitation only attains a maximum for the lowest welding current and automatically drops as the welding current increases and is practically zero when the welding current is at a maximum.

Oscillographic records given in Fig. 2 were taken on machines of fundamentally different designs but of practically identical output—about 220 A continuous current at 25 V. The data which concern the dynamic qualities of the machines are given in the following table. The current adjustment corresponds to about one-fifth of the constant welding current.

TABLE I.

Design of machine	a and b	c	d (Type QGS 60)
Absolute recovery voltage	10 V	22.8 V	33.3 V
Apparent resistance or relative recovery voltage ..	0.059 V/A	0.232 V/A	0.295 V/A
Current surge at circuit closing ..	530 A	200 A	178 A
Time necessary for establishment of approximate stable short-circuit current..	about 4 s.	about 2 s.	about 0.5s.

Compare with oscillographic records given in Fig. 2.

The most important criterium is the relative recovery voltage or so called apparent resistance. Disregarding the internal resistance of the generator, the apparent resistance is of the same order of importance as a steadying resistance or, in other words, a machine with an apparent resistance of x ohms gives practically the

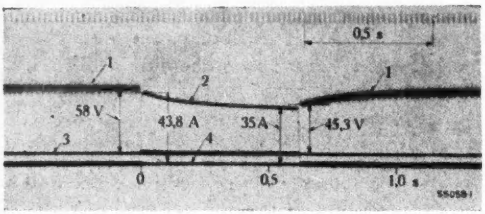


Fig. 3. Welding generator for thin sheeting. Switching in and out from no load to short circuit and vice versa.
Adjustment 20 A at 25 V.
(1) No load voltage
(2) Short circuit current
(3) Zero axis of voltage
(4) Zero axis of current.

same welding performance as a very slow reaction machine or a constant source of current in the circuit of which x ohms has been inserted. The fundamental difference is that the latter arrangement wastes power, while the apparent resistance works without losses as a result of sudden suitable variations of the e.m.f.

While the very low recovery voltage of machine a–b does not allow a re-ignition without additional resistance, this defect is already overcome in the instantaneous reaction generator c of earlier design, as its apparent resistance is roughly four times bigger. For this reason, its current peak at circuit closing on the short-circuit is much lower while its drop back to stable short-circuit magnitude takes place much quicker. With generator d, there is a very big apparent resistance and the time required to bring the current down to its stable value after the circuit-closing surge is very short.

With the oscillograms of Fig. 2, the currents adjusted to are made only about 1/8 of the maximum current intentionally, because in this range, difference in dynamic qualities are especially evident. If the current adjusted to is made bigger in the case of machine d, the oscillographic record changes, the current peak soon

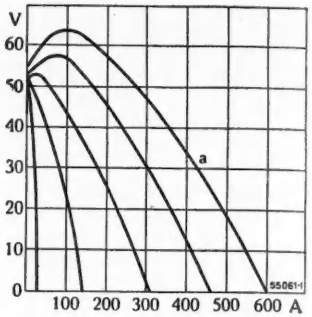
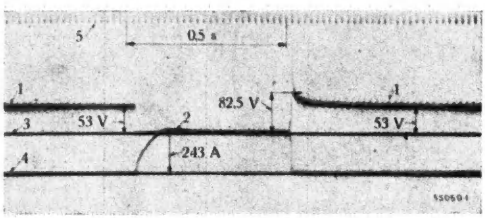


Fig. 5. Static characteristics.
Welding generator for 30-400 A at 25 V. (*a*) Maximum adjustment with machine at running temperature.

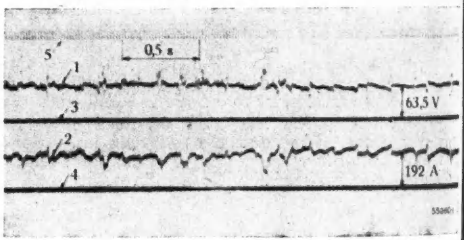
disappearing altogether and the recovery voltage immediately jumping back to the no-load value set for.

Fig. 3 shows the oscillogram of a welding machine for thin sheeting for an adjustment of only 20 A at 25 V. A notable feature is the very big apparent resistance of 1.3 ohms. Finally, Fig. 4 shows records of a special machine for copper welding. In service, it requires an arc voltage of about 60 V and this makes very severe demands on its welding properties. The good dynamic features—immediate voltage recovery to a value of over 80 V, no circuit-closing peak— as well as the welding oscillogram show that this generator as well fulfils its duties completely. Here it is very important that, despite the high welding voltage, it should be possible to keep the no-load voltage at values admissible for the welder, that is 50 to 55 V. The momentary rise to about 80 V has dropped very appreciably after 1/10 second.

The external characteristics of Fig. 5 were recorded on machine d. Thanks to the designing principles the regulating range attained is exceptionally big. Further it can be worked over smoothly and without changing connections.



I. Switching in and out processes from no load to short circuit and vice versa.
Adjustment 100 A at 65 V



II. Welding oscillogram.
192 A welding current, 63.5 V.

Fig. 4. Generator for high voltage electrodes (for welding copper).
(1) No load and welding voltage respectively
(2) Short circuit current and welding current respectively
(3) Zero axis of voltage
(4) Zero axis of current
(5) Time scale.

TECHNICAL NEWS

Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.

Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.

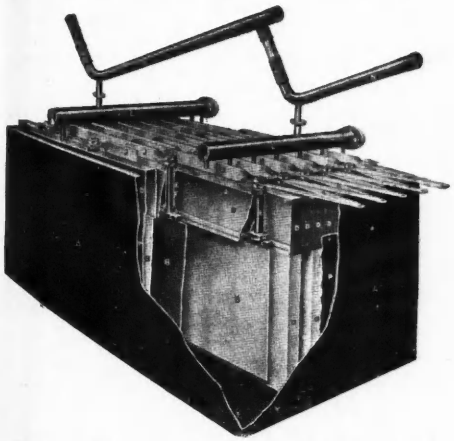
- NEW EQUIPMENT
- BOOKS AND CATALOGUES
- BUSINESS CHANGES
- PERSONAL
- NOTES

INTERNATIONAL ELECTROLYTIC PLANT CO., LTD., SANDYCROFT, NEAR CHESTER.

THERE are several methods of producing hydrogen commercially, and one of the cleanest and least troublesome is by the electrolysis of water, which produces gas of very high purity, 99.95% and over, and also gives simultaneously the important by-product, oxygen.

The International Electrolytic Plant Co. Ltd., manufacture the "Knowles" cells for electrolysing water, ranging from small sizes producing 8 cubic feet of hydrogen per hour, to ones giving 164 cubic feet per hour, with 10,000 ampere loading. All cells are of steel construction, and can be easily erected and dismantled, as no large joints are used in their construction. The standard type of electrodes are made from flattened steel sheets, with pure iron bolts welded on for leading the current to them. An improved type of electrode, with copper leads, has been developed and marketed, enabling twice the current to be passed, thus doubling the output of gas without otherwise modifying the construction or size of the cell.

The plant which consists of a number of cells in series is also equipped with special apparatus to continuously feed the cells to their correct level with distilled water, wash the gases, and maintain an equal gas pressure on either side of the cell diaphragms, so preventing any possibility of the hydrogen and oxygen mixing.



Rockman Soldergun. The Rockman Engineering Co., Ltd., 2, Buxton Street, Manchester 1, has announced a new pat. Solder Gun fitted with a Push Button by which half the resistance can be cut out and wattage and temperature can be increased by 100 per cent. Thus soldering temperature is reached within 90 secs. The 50 to 60 Watt by released button is sufficient to maintain the temperature in the bit, and it prevents at the same time corrosion of the copper. The innovation has proved to be very economical in works where soldering is done in continuous shifts.

Association for Scientific Photography. This Association has been formed to promote interest in the use of photography in all branches of science, technology and medicine, and also to assist members in applying photographic methods to the solution of particular problems. The field covered by the Association will include Radiography, Colour Photography, Photomicrography, and Sub-standard Kinematography in all its branches. The Committee of the Association consists of Professor J. Yule Bogue (Chairman), S. Boyle, Miss K. C. Clark, G. A. Jones, E. H. Le Mon, Dr. H. Mandiwall, C. D. Reyersbach, G. H. Seewell, and R. Mc. V. Weston, whose address is Houndwood, Farley, Salisbury, Wilts., and who would give any further information regarding membership, etc., upon request.

The Institution of Heating and Ventilating Engineers. Professor Sir Alfred Egerton, F.R.S., will lecture on the meeting of this Institution to be held on Wednesday, the 1st September, at 6 p.m., in the Council Room at 21, Tothill Street, London, S.W.1.

Change of Name. Messrs. Modern Pressings and Engineers Ltd., announce the Change of Name of the Company to : Dean and Mulhall Ltd., 27-28, Sidney St., Sheffield 1.

BOOKS AND CATALOGUES RECEIVED.

Aviation Dictionary and Reference Guide.—By Harold E. Baughman, Aero Publishers, 120, North Central Avenue, Glendale, Calif., U.S.A., 906 pp., 6 × 9½ in., price $6.50. Mr. Baughman deserves to be congratulated to this admirable effort. His dictionary of 4,500 terms has been compiled with the co-operation of the aeronautical staff of Aero Publishers and with the assistance of a great number of aeronautical firms and technical schools. It consists of a Dictionary of Terms and Abbreviations, of Directory Information, and of Reference Sections of Flying, Aircraft Design and Production. This book will be a most welcome addition to the libraries of all institutions, firms, and individuals with connection to aeronautical engineering and science.

ASLIB Guide to Special Information. The Association of Special Libraries and Information Bureaux, 31, Museum Street, London, W.C.1, has just published No. 5 of the War-time Guides dealing with Engineering, other than Electrical and consisting of 58 foolscap sheets, mimeographed. It contains a list of Government Departments, Professional, Research and Trade Organizations, Educational Organizations, Selected items relating to fuel, transport, raw materials, etc., and a List of Periodicals and Year Books. The price is 5s. to full members of ASLIB, 6s. to others, post free.

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Bibliography of Indium.—The Indium Corporation of America, 60 E. 42nd Street, New York City, has just published a booklet of 36 pages containing the 1941-1942 supplement to the Bibliography of Indium, as compiled by M. T. Ludwick, Assistant to the President of the Company. The booklet is an extremely valuable source of reference, and also of information as not only the Authors and the titles of the articles and papers, but also a short abstract of most of them has been included. Copies may be obtained on application.

Photography as an Aid to Scientific Work. A revised edition of this booklet of 16 pages gives a great amount of useful details on Ilford Films, Plates, and Filters, in regard to their application to scientific work, including Biological Sciences, Chemistry and Physics, Geology, Mineralogy and Petrology, Medicine, Metallurgy and Metallography. Copies of the booklet may be obtained from Messrs. Ilford Ltd., Ilford, London.

Practical Sheet and Plate Metal Work.—By E. Arthur Atkins, M.Sc., M.I.Mech.E., M.I.W., Sir Isaac Pitman & Sons, Ltd., London, 606 pp., 5 × 7 in., price 10/6. Increased application of sheet metal has made desirable a fifth revised edition of the popular book of Mr. Atkins, which, already in its former editions, has proved its value as a reference book to engineers and workmen engaged in the sheet metal industry. The new edition has been brought up to date, and in this book accumulated information revised in accordance with the results of most recent research and practical experience.

Technique of Plywood. By Chas. B. Norris, I. F. Laucks Inc., 911, Western Ave., Seattle, Washington. 249 pp., 4 × 7 in. Price $2.50. This book is a valuable contribution to the technical literature by one of the pioneers of wooden structures. The subject matter is divided into five parts :—Strength, Deformation and Elastic Stability of Plywood Sheets, Elastic Theory of wood and Plywood, Manufacture of Plywood, Warpage of Plywood, Bending, Moulding and Embossing of Plywood. An additional chapter deals with the general scientific principles of gluing. The formulæ included give quantitative information which should be particularly helpful to engineers engaged in the design of structures employing plywood stressed skin coverings. Many of the formulæ originally derived for homogeneous materials, such as steel, were rederived by the Author for use in connection with plywood.

Tin and its Uses. No. 14 of this Review, just published after an interval of some ten months, discusses the future of tin in some of its principal uses, e.g., tinplate and solder, with reference to the effect on post-war markets of the substitutes and modified techniques which have been adopted to meet the tin shortage. It is shown that, in general, efforts to use less tin have involved higher working costs or lower service value.

An article on tin in bearing alloys explains the relative merits of tin-rich bearings and the various alternatives. Illustrations show the Typhoon and Beaufighter aircraft, and the Churchill heavy tank, all of which are driven by engines fitted with tin-rich bearings.

Copies of the Review may be obtained free of charge from the Tin Research Institute, Fraser Road, Greenford, Middx., or from the Battelle Memorial Institute, Columbus, Ohio, U.S.A.

PERSONAL.

Mr. P. G. Bradford, M.I.Mech.E., has been appointed Director of Civil Armaments Production in Calcutta.

Mr. E. J. Hudson, A.M.I.Mech.E., has been appointed Manager of Crompton-Parkinson Ltd.

Mr. Lawrence Levy, who has been Chairman of Messrs. George Cohen, Sons & Co., Ltd., since 1928, has recently completed his fiftieth year of service with the firm.

Mr. Eric Mensforth, of the Westland Aircraft Ltd., has been appointed Chief Production Adviser to the Ministry of Aircraft Production.

Mr. G. C. Oram, M.I.Mech.E., has been appointed General Works Manager of the Phoenix Steel Tube Co. Ltd.

Mr. C. B. Wilks has been appointed Works Manager of Hayward-Tyler & Co. Ltd.

Mr. Denis E. Wiseman has been appointed General Manager of Short and Harland Ltd., Belfast.

KING'S HONOURS FOR ENGINEERS AND SCIENTISTS

K.B.

Hugh Eyre Campbell Beaver, Director-General, Ministry of Works.

Capt. John Paul Black, Managing Director, Standard Motor Co. Ltd.

John Craig, Chairman and Managing Director, Colvilles Ltd.

Harold Spencer Jones, Astronomer Royal.

John Macfarlane Kennedy, Deputy Chairman, Electricity Commission.

Archibald McKinstry, Deputy Chairman and Managing Director, Babcock and Wilcox Ltd.

George Paget Thomson, Prof. of Physics, Imperial College of Science and Technology.

C.B.

W. S. Farren, Director, Royal Aircraft Establishment, Ministry of Aircraft Production.

C.I.E.

L. N. Flatt, Director of Mechanical Engineering, Railway Board, Govt. of India.

A. R. E. Lockhart, Dep. Director-General (Munitions), Govt. of India.

R. Lean, Chief Mechanical Engineer, Madras and Southern Mahratta Railway, Madras.

J. A. Stein, Chief Engineer, Communications and Works Dept., Bengal.

Kahn Bahadur Muhammad Sulaiman, Additional Chief Engineer, Public Works Dept., Govt. of India.

C.B.E.

G. C. Boulter, Chief Engineer, Merchant Navy.

R. Chadwick, Chief Designer and Director, A. V. Roe & Co. Ltd.

F. J. Dixon, Chief Engineer, South Staffordshire Water Works Co.

E. S. Grummel, Chairman, Fuel Efficiency Committee.

H. L. Guy, Chairman, Gun Design Committee, Scientific Advisory Council, Secretary, Institution of Mechanical Engineers.

J. S. Hollings, Chairman, Anti-Glare Advisory Committee, British Iron and Steel Federation.

H. Main, Managing Director, Caledon Shipbuilding and Engineering Co.

A. J. Palmer, Director, Vickers-Armstrongs Ltd.

R. K. Pierson, Chief Designer, Vickers-Armstrongs Ltd.

A. S. Quartermaine, Chief Engineer, G.W.R.

P. J. Ridd, Dep. Chief Engineer, G.P.O.

V. A. M. Robertson, Chief Engineer, L.P.T.B.

C. S. Robinson, Director-General, Filling Factories, Min. of Supply.

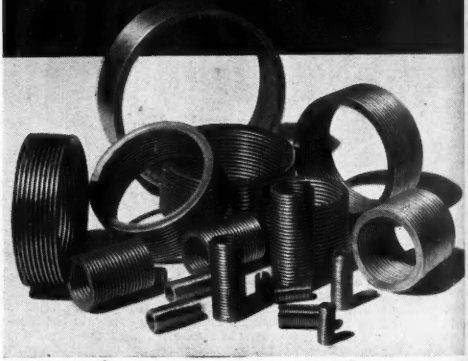
A. W. Smith, General Manager, Birmingham Gas Dept.

B. N. Wallis, Assist. Chief Designer, Vickers-Armstrongs Ltd.

CORRECTION.

The Influence of Deformation on the Internal Loads of Beams with a Straight Axis. (Page 133 of our May, 1943, issue). In all formulas where m, q, and n occur M_1, Q_1, and N_1, should be read instead. $\bar{m}$, $\bar{q}$, $\bar{n}$, should be read, $\bar{M}_1$, $\bar{Q}_1$, and $\bar{N}_1$, respectively.

METALLIC BELLOWS



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